Evaluating different value adding processing systems for bamboo developments

Martin Dewald Burger

Thesis presented in fulfilment of the requirements for the degree of Master of Engineering (Industrial Engineering) in the Faculty of Engineering at Stellenbosch University

Pectora roborant cultus recti

UNIVERSITEIT
iYUNIVESITHI
STELLENBOSCH
UNIVERSITY

100
1918 · 2018

Supervisor: Prof. G.A. Oosthuizen

March 2018

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

March 2018

Signature Date

Abstract

Evaluating different value adding processing systems for bamboo developments

M.D. Burger
Department of Industrial Engineering
University of Stellenbosch
Private Bag X1, Matieland 7602, South Africa
Thesis: MEng (Industrial)
March 2018

Mining contributed significantly to South Africa's economic growth, but with the closure of mining operations several challenges arise. These challenges include land remediation, mine rehabilitation and dust control. This in combination with waste water and tailings management creates several environmental challenges. At the same time the socio-economic challenges and external obligations from government make the sustainability of mining very difficult. As these natural resources are depleted, it is critical to investigate ways to transform current liabilities into sustainable assets that can create shared value for both the mining company and community in which it operates.

This research study attempts to address these challenges by investigating the possible opportunities when planting Bamboo on these closed mining sites to generate new economic activities, rehabilitate the soil and create livelihoods for the families left behind by terminated mining operations.

In this study, possible applications or value-adding systems are explored to create sustainable value by planting bamboo on old mine sites and manufacture products from this bamboo. The project at hand considers a development of 1000 hectares. This is the size of the final development and it might take place in phases.

The first objective was to understand the value creation possibilities for bamboo applications. Several applications were considered and with the needed advice from the industry, it was decided to investigate four applications or value-adding systems in detail. This included Charcoal, Biochar, Activated Carbon and Laminated Bamboo Board.

The second objective was to identify key elements to consider and to understand the bamboo supply capacity for the selected defined project. Seven possible available biomass scenarios were established. These scenarios made provision for different yields and development phases.

The third goal was to develop a financial study estimate model to validate the different scenarios. This led to the fourth goal which was to validate the financial study estimate model with selected bamboo value creation systems based on the key elements and supply capacity and to identify feasible solutions. The seven different biomass scenarios in combination with the four different value systems, meant that there were a total of 28 different scenarios. Quotations obtained from industry were configured by means of the Lang factor method to comply with all the scenarios.

Thereafter, a feasibility study was conducted by using the financial model to gain an estimate with a detail level referred to as a study estimate. Seven of the scenarios had a positive NPV within the 10-year project evaluation period. In the feasibility study, the Activated Carbon 100 000 ton scenario had the highest NPV with an amount of R729 472 351.10 and it breaks even in year 2. The 100 000 ton Laminated Board scenario had the second highest NPV with a value of R639 777 550.44, it also broke even in year 2. The latter scenario had a much higher Capex and Opex. The final objective was to conduct a further risk analysis on the seven feasible solutions and to determine the best fit for the set criteria (which included a sustainable development criteria for the project.)

The risk analysis included a sensitivity analysis which was done by the means of a Monte Carlo simulation. The inputs that were varied in this analysis included the cost of raw material, product selling price, labour cost, interest rate, production efficiency and the fixed capital cost. The two scenarios that performed the best in the feasibility analysis also performed the best in the risk analysis. The Activated Carbon 100 000 ton scenario which had the highest positive NPV in the feasibility analysis had a probability of 92.5 % to have positive NPV with a mean NPV of R425 018 426.87. The 100 000 ton Laminated Board scenario had a higher mean NPV of R1600 million and a higher probability of 94.5% to have a positive NPV. The Laminated Board scenario performed the best in the sustainable development index creating 346 jobs, 265 more jobs than the 100 000 ton Activated Carbon scenario.

It was concluded that a laminated board value creation system with access to 100 000 ton of raw bamboo per annum is the best option for the given 1000 ha bamboo project.

Opsomming

Die evaluering van verskeie waarde toevoegings stelsels met bamboes ontwikkelings

M.D. Burger

Departement van Ingenieurswese

University of Stellenbosch

Privaat Sak X1, Matieland 7602, Suid-Afrika

Tesis: MIng (Bedryfs)

Maart 2018

Wanneer 'n mynbedrywigheid die einde van sy leeftyd bereik, laat dit 'n ekonomiese, omgewings- en maatskaplike uitdaging. Hierdie projek poog om hierdie uitdagings die hoof te bied deur nuwe ekonomiese aktiwiteite te skep, die grond te rehabiliteer en om lewensonderhoud te skep vir die gesinne wat agter gelaat word deur beëindigde mynbedrywighede .In hierdie studie word moontlike toepassings of waardetoevoegingstelsels soos wat dit na verwys word in die dokument, ondersoek met die doel om volhoubare waarde te skep deur bamboes op ou mynhope te plant en produkte van die bamboes te vervaardig. Die voorgestelde projek ondersoek 'n ontwikkeling van ‘n 1000 hektaar. 1000 hektaar is die grootte van die finale ontwikkeling en die moontlikheid bestaan dat dit in fases kan plaasvind. Vyf projek doelwitte word ondersoek in hierdie studie. Die eerste doel was om die waardeskeppingsmoontlikhede vir bamboes toepassings te verstaan. Verskeie toepassings is oorweeg en met die nodige advies van kenners van die industrie is daar besluit om vier toepassings of waardetoevoegingstelsels in detail te ondersoek. Dit sluit in Charcoal, Biochar, Geaktiveerde Koolstof en Gelamineerde Bamboes borde. Die tweede doelwit was om sleutelelemente te identifiseer om die bamboeskapasiteit vir die geselekteerde omskrewe projek te oorweeg en te verstaan. Sewe moontlike beskikbare biomassa scenario's is opgetrek. Hierdie scenario's het voorsiening gemaak vir verskillende opbrengste en ontwikkelingsfases. Die derde doel was om 'n finansiele studieberamingsmodel te ontwikkel om die verskillende scenario's te evalueer. Dit het gelei tot die vierde doelwit waarin die finansiële studieberamingsmodel geevaleer moes word met geselekteerde bamboes waardeskeppingstelsels gebaseer op die sleutelelemente en aanbodkapasiteit en om dan haalbare oplossings te identifiseer. Die sewe verskillende biomassa scenario's in kombinasie met die 4 verskillende waardeskeppingssisteme, het beteken dat daar 'n totaal van 28 verskillende scenarios was. Kwotasies wat van die nywerheid verkry is, is aangepas met behulp van die Lang faktor metode om by al die scenarios in te pas. 'n Haalbaarheids analise is uitgevoer deur die finansiële model te gebruik om 'n skatting te kry met 'n detailvlak wat as 'n studieberaming bekend staan. Sewe van die scenario's het 'n positiewe NHW binne die 10 jaar projek evalueringsperiode gehad. In die haalbaarheids analise het die Geaktiveerde Koolstof 100

000 ton scenario die hoogste NHW met 'n bedrag van R 729 472 351.10 gehad en dit breek in 2 jaar gelyk. Die 100 000 ton Gelamineerde Bamboes bord-scenario het die tweede hoogste NHW met 'n waarde van R 639 777 550.44 gehad ,dit het ook in jaar 2 gelyk gebreek. Die laasgenoemde scenario het 'n veel hoër Capex en Opex gehad. Die finale doelwit was om 'n verdere risiko-analise te doen oor die sewe haalbare oplossings en om die beste geskikte scenario vir die vasgestelde kriteria te bepaal (wat 'n volhoubare ontwikkelingskriteria vir die projek insluit het.) Die risiko-analise het 'n sensitiwiteitsanalise ingesluit wat met behulp van ‘n Monte Carlo simulasie gedoen is. Die insette wat in hierdie analise gevarieer is, het die rou materiaalkoste, produkverkoopprys, arbeidskoste, rentekoers, produksie-doeltreffendheid en die Vaste kapitaalkoste ingesluit. Die twee scenario's wat die beste presteer het in die Haalbaar analise, het ook die beste in die risiko-analise presteer. Die 100 000 ton-scenario van Geaktiveerde Koolstof wat die hoogste positiewe NHW in die Haalbaarheidsanalise gehad het, het 'n waarskynlikheid gehad van 92,5% dat dit ‘n positiewe NHW met 'n gemiddelde NHW van R425 018 426,87 sou hê. Die 100 000 ton Gelamineerde Bamboes bord scenario het 'n hoër gemiddelde NHW van R 1600 miljoen en 'n hoër waarskynlikheid van 94,5% om 'n positiewe NHW te hê. Die Gelamineerde Bamboes bord scenario het die beste in die volhoubare ontwikkelingsindeks behaal, dit skep 346 werksgeleenthede, 265 meer werksgeleenthede as die 100 000 ton Aktiveerde Koolstof-scenario. In die lig hiervan het die studie tot die gevolgtrekking gekom dat 'n Gelamineerde Bamboes bord waarde-skepstelsel met toegang tot 100 000 ton rou bamboes per jaar die beste opsie vir die gegewe projek is.

Acknowledgements

I would like to thank the following people:

- The Lord Jesus Christ for his continual guidance, He is my source of joy power and gives me a purpose in this life.
- Dr G.A. Oosthuizen for being both my supervisor and mentor during this project.
- My family for their support and love.
- All my friends especially Francois, Louis, Jarryd and Jan – Louis, we stayed together, worked on our theses together and had great fun together.
- Wilhelm Durr for assisting me in designing the financial model.
- Konrad von Leipzig and WG Bam for answering my questions on the financial modelling.
- Dr Hoffman for his advice on calculating the bamboo moisture content
- Dr. Raymond Els for his advice with the Lang factor method
- Mr. Graham Dunbar from Brightfields in Cape Town for his assistance and advice from an industry perspective.
- Dr. Emad Uheida for his patience and guidance with the layout and general willingness to assist me.
- Mr Peter Perce from Bamboo de Afrique for all his time and advise. For all expeditions to cut bamboo for experiments. Without your help this project would not have been a success.

•

Table of contents

List of Figures

List of Tables

Nomenclature

Abbreviations

AD	Anno Domini
C	Purchased Cost
CDM	Clean Development mechanism
CEPCI	Chemical Engineering Plant Cost Index
GHG	Greenhouse gas
H	Hours
HDI	Development Index
HSDI	Human Sustainable Development Index
I	Cost index
INBAR	International Network for Bamboo and Rattan
ITTO	International Tropical Timber Organization
LBL	Laminated Bamboo Lumber
LVL	Laminated Veneer Lumber
NPV	Net Present Value
PAH	Polycyclic Hydrocarbons
PSL	Parallel Strand Lumber
SARS	The South African Revenue Services
SSA	Sub-Saharan Africa
TU Berlin	Berlin Institute of technology
VAT	Value-Added Tax
WCED	World Commission on Environment and Development

Units

˚C	Degrees Celsius
Kcal	Kilocalories
MJ	Mega Joule
pH	Potential of Hydrogen
KOH	Potassium hydroxide
g/m^2	Grams per meter squared
kPa	Kilopascal
kN	Kilonewton
mm/min	Millimeter per minute
in	Inch

ft	Feet
c/kWh	Cent per kilowatt hour

Constants

n	0.6

Variables

A	Payment Amount per Period
$A_{a/b}$	Equipment cost attribute
C	Purchased cost
C_i	Inflated cost
C_{OL}`	Cost of Operating Labour
COM	Cost of Manufacturing
COM_d	Cost of Manufacture excluding depreciation
C_p	Cost in the base year
$C_{p,i}$	Purchased Cost for Major Equipment Units
C_{RM}	Cost of Raw Materials
C_{TM}	Capital Cost (Total Module) of Plant
C_{UT}	Cost of Utilities
C_{WT}	Cost Waste Treatment
D	Depreciation Value
DMC	Direct manufacturing Costs
FCI	Fixed Capital Investment
f_i	Inflation in year i
F_{Lang}	The Lang Factor
FMC	Fixed Manufacturing cost
GE	General Expenses
I	Cost index / Sustainable development index
i	Interest Rate
m	Number of Compounding Periods per year
MC%	Moisture Content
n	Number of Payments or Periods
P	Initial Loan Amount
POP + I	Payback Period Plus Interest
PVR	Present Value Ratio
r	Interest rate per Period
R	Revenue from Sales

ROI	Return on Investment
S	Salvage Value
t	Tax Rate

Subscripts

a	Equipment with the required attribute
b	Equipment with the base attribute
1	Base time when the cost is known
2	Time when the cost is desired
eff	Effective annual Interest Rate
nom	Given Nominal interest Rate
NPV	In context of Sustainable Development Index
Risk	In context of Sustainable Development Index
Jobs	In context of Sustainable Development Index
Carbon	In context of Sustainable Development Index

Chapter 1 Background and Motivation

A man can live in a bamboo house under a bamboo roof, sit on a bamboo chair at a bamboo table, with a bamboo hat on his head and bamboo sandals on his feet. Simultaneously he can hold in one hand a bamboo bowl, in the other, bamboo chopsticks and eat bamboo sprouts. When done with his meal, which has been cooked over a bamboo fire, the table may be washed with a bamboo cloth, and he can cool himself with a bamboo fan, take a siesta on a bamboo bed, laying on a bamboo mat with his head resting on a bamboo pillow. His child might be lying in a bamboo cradle, playing with a bamboo toy. On rising he would smoke a bamboo pipe, using a bamboo pen, whilst writing on bamboo paper, and carry his articles in bamboo baskets suspended from a bamboo pole, with a bamboo umbrella over his head. He might then take a walk over a bamboo suspension bridge, drink water from a bamboo ladle, and scrape himself with a bamboo scraper (handkerchief).
From "A Yankee on the Yangtze" by William Edgar Geil [1].

Bamboo is by far the single most important plant in forests in rural communities in tropical areas and it is used to produce items from the cradle to the coffin. In recent years the demand for this material passed the availability which is causing the exhaustion of resources in some areas as a result of over-exploitation [2]. The potential of bamboo in Africa is under-exploited. Bamboo can prove to be a significant link for developing countries in Africa to shift to a greener economy.

During the 20th century, forests were assessed to determine the commercial value of its timber. No other major economic importance was linked to the other components of the forests. In the 20th century, vast areas of tropical forests were exploited, during this process, bamboo and other non-wood products were destroyed or disregarded in the logging operations. During our current century, there is a growing awareness that these non-wood products in these forests are critical for eco-systems and serves an important means of support to lives of the local communities. It is a source of foreign exchange and its gaining significance globally as a valuable commodity, this is driven by the disturbing deforestation rate and a decreasing timber yield [3].

South Africa as a country is blessed with rich mineral resources and extensive mining activities are conducted all over the country. It contributes to about 7.7% to the GDP and creates 1.4 million jobs yet from an environmental perspective it leaves a destructive path [4].

At this point, the reader might ask what exactly do mining and bamboo have in common? In this study, the possibility of establishing commercial bamboo plantations on old mine sites in conjunction with value-adding processes are investigated. The study investigates the feasibility and models the risk of such operations and concentrates on four value-adding processes. This study dives deep into the cost of setting up a Bamboo Charcoal, Bamboo Activated Carbon, Bamboo Biochar and Bamboo Laminated Boards production facilities. It aims to draw a conclusion on which value-adding process will be the most feasible, have the least amount of risk and creates the most value.

1.1 The rationale of the research

Mining contributed significantly to South Africa's economic growth, but with the closure of mining operations several challenges arise. These challenges include land remediation, mine rehabilitation and dust control. This in combination with waste water and tailings management creates several environmental challenges. At the same time the socio-economic challenges and external obligations from government make the sustainability of mining very difficult. As these natural resources are depleted, it is critical to investigate ways to transform current liabilities into sustainable assets that can create shared value for both the mining company and community in which it operates.

This thesis attempts to further the use of this wonderful and useful plant to solve this problem, by rehabilitating the destruction left by mining activities. It endeavours to find a solution and to create jobs for communities that are left behind by mines that ceased production activities. This thesis takes a crack at killing two birds with one stone. This is done by inducing economic activities into jobless mining communities left behind at deserted mining operations, whilst beautifying and restoring life to the environment. The research problem is to explore bamboo application or value-adding systems and conclude on the best option for a 1000 hectare development on old mine sites. This study does not focus on the agricultural side of the project but on the financial feasibility and risk associated with different possible agro-processing solutions.

The lack of knowledge with regards to the potential of certain species serves as a great obstacle in the capacity of the earth to provide for its residents. This leads to some species being over utilised while other potentially useful species are allowed to be wasted. An example of this is breadfruit (*Terculia africana)* which is consumed as a delicacy in eastern Nigeria by the Igbo people, while it is allowed to waste by the Guyaka community of Qua'an pan Government area in the Plateau state which is located more to the centre of the country [3].

This thesis aims to develop the opportunities that bamboo provides in Africa and to serve as a small stepping stone in lifting Africa out of poverty in a sustainable way. Although the thesis focuses on a small aspect of bamboo it will hopefully create awareness of the possibilities that bamboo offers and drive the need to plant more bamboo and explore further opportunities.

The calculations to determine the feasibility of the commercial farming of the bamboo on the mine sites have been done by industry. This study focuses on secondary economic activities. These activities refer to activities that add value to the raw bamboo. The four value-adding systems were selected with counsel from the study leader and industry.

1.2 Research objectives

The research objective were constructed to provide a framework for a concise and well-structured document to address the problem statement. Five main research objectives were identified to serve this purpose:

- Understand the value creation possibilities for Bamboo applications.
- Identify key elements to consider and the bamboo supply capacity for the selected defined project.
- Develop a financial study estimate model that considers different development sizes and phases.
- Validate the financial study estimate model with selected bamboo value creation systems based on the key elements and supply capacity to identify feasible solutions.
- Conduct further risk analysis on feasible solutions to determine the best fit for the set criteria.

1.3 Research methodology

The project goals served as a guideline in the literature study but still allowed freedom to explore the project problem statement. An in-depth study on bamboo was done, which gave a better understanding of what the plant had to offer. The literature study explored financial models and investigated the essence of value and value creation. Certain assumptions were made. The scope was defined and four value-creating systems where identified. Certain scenarios were set and a financial model was built. Quotations were obtained for each value creating system and these quotations were scaled to align it with the different scenarios. The Lang method was used to establish a study estimate of the cost and feasibility of each value-creating system. A risk analysis was done on all the scenarios that were deemed feasible. It was then concluded, which scenario adds the most value.

1.4 Scope of work

This project covers a broad array of subjects, therefore, it is important to define the scope of the project and more specific assumptions and limitations for the work.

This study will investigate the agro-processing of four bamboo products. They are referred to as value-adding systems in the study. It will not investigate the agricultural forestry of the bamboo. It is assumed that the bamboo raw material is bought from these operations.

The study does not look at the distribution and marketing of the final products. The financial estimates level of detail is sufficient for a study estimate. The financial figures were obtained in the period from 2016 to 2017.

Chapter 2 Literature study

2.1 Value Creation

2.1.1 Introduction

Climate change is a buzz word of our day and time, the question still remains whether it is caused by human activity or a natural cyclical phenomena. What is clear is that the increasing intensity already affects economics. Sustainable value creation can decelerate climate change and the economic effects. The major challenges of the 21st century are the design, valuation and maintenance of such production systems within the limits of renewable energy production and social compatibility [5]. This Chapter defines sustainability and value creating to develop an understanding of what is meant by this. The bamboo project must be evaluated in this context.

According to Emec [5], the term value refers to the magnitude of economic, environmental and social benefits when raw materials are transformed or when services are delivered. The value adding process is called production and water and energy is required for this transformation. Other factors needed are all related to processes, equipment, organization and people.

Sages in Greece were the first to document the investigation of value. Axiology is a discipline that deals with values in a more systematic way. It is a combination of ‘axios’ signifying worthy or valuable and ‘logos’ meaning reasoning or discourse. Through the ages, different philosophers reflected on value and what is meant. Plato and Aristotle held value as an absolute reality and that it existed. Epicurus, on the other hand stated, that the human pursuit of pleasure is where value lies, or at least in a limited sense. People strive to maximise pleasure and minimise pain. His thoughts lead to the theory of Egoism and later Utilitarianism. Utilitarianism embraces the thought that an action’s moral worth is determined by what it contributes to overall utility, in other words, what it contributes to the pleasure of people [6].

Rickert later designed Wertphilosophie which studies the human value judgement. He reckoned that values could be treated as intersubjective rather than subjective. Freud studied the natural values from an unconsciousness viewpoint. Piaget investigated value from the viewpoint of a child’s cognitive development. Later as part of the behaviourism movement in the early 20th century, values were studied from a viewpoint of learning, and where punishment was used to observe different behaviour changes. The Humanistic Psychology works of the 20th debated different value problems. Maslow developed the well-known hierarchy of human needs which defines values from the perspective of fundamental human needs. Most psychological research areas shied away from tough problems such as value, morality and creativity while Maslow confronted them [6].

2.1.2 Value from an economic and engineering point of view

Quesnay developed a theory which is often described as the origin of economic theories in the middle of the 18th century. He described value as being the net volume of net products of its industries, not necessarily stocks of silver and gold. Agriculture was counted as the only activity that produced a net product. Adam Smith reinforced these ideas with his "Wealth of Nations" theory. Smith argued that value can be classified as 'use-value' and 'exchange value'. Use value can be described as the utility or usefulness of a product. Exchange value is seen as the amount or quantity with which a product can be exchanged for another product. Smith regarded labour as the true exchange for value [6].

In the 1870's the marginal utility theory was developed independently by Menger, Jevons and Walrus. They focused on the idea of utility and tried to reconcile use value and exchange value. They described it as marginal utility, it was seen as the personal satisfaction of a consumer that springs from using one extra unit of product. This means that an individual's demand for a product is dependent on the marginal utility of a product and not as the total utility.

Switching from economic values, how is value viewed in engineering? Engineering is mainly concerned with producing services or goods that have a higher function but at a lower cost. Even though the meaning of lower cost is easily understood from an economic perspective, higher function is not defined so easily [6].

In value engineering developed by general electric during the 2nd world war, function was examined in an attempt to improve the value of goods and services. Value Engineering defined value as the ratio of function to cost. This suggests that value can be increased by either improving the function or by reducing the cost. This thought might be relevant when there is an attempt to lower the cost of a product by using different materials while still maintaining the function. In this process the value of a product must be evaluated from several viewpoints, this includes basic function quality and customer satisfaction. It can be hard to define, but it includes several aspects such as happiness, comfort, good price and pride of ownership [6].

2.1.3 Evolution of value creation

In essence, manufacturing is synonymous with creating value, but one must take a deeper look at what value creation entails. Functionality is not the only role player in attaching value to an artefact. This has become more apparent in the current century specifically with regards to rapid globalization of markets and vast networking of information. Monostori [6] presents a few factors instigated by market globalization. It changed the industrial structures and has prompted labour specialization.

The gap in the economic disparity of nations has widened as a result and price competition has intensified. The transformation of goods and services into commodities is another outflow of market globalization. What is meant by this, is that a product that has a good functionality loses its meticulousness and becomes just another ordinary product as other products may have the exact function, possibly at a lower price. Producers are forced to investigate not only the functionality of a product but how it can maximise the value it offers to its possible clients. In an attempt to increase the value offering many manufactures are paying more attention to marketing and service businesses [6].

Globalization drives two conflicting outcomes: 1) In order to survive the price competition presented by globalization companies specialize, 2) and in order to survive the value competition companies expand their business activities [6].

Information networking initiated its own unique changes. Product and service diffusion is hastened while their lifestyles are shortened. The internet can influence the value attached to products and other customer's opinions of products, by learning of other customers' preferences. The two contradicting movements initiated by information networking are 1) the diversification of consumer's preferences and 2) homogenizing of lifestyles and values. A products' value is determined through the interaction with consumers, products and their producers in society. Another aspect that goes hand in hand with globalization and networking is sustainable development. Every industry in the 21st century is obliged to contribute to sustainable development. Maintaining sustainability can uncover the fact the values of a whole society can differ from that of certain individuals. This emphasises the need to look into value creation mechanisms [6].

Satisfaction is the most important contributor to value in the Human system. Goods are judged by the amount of value consumer will get from using them.
Naturals systems bring another curveball into play if it is included amongst the interaction of systems. In the current day and age, the magnitude of the impact that humans have on the planet and on the ecological systems to be more specific is becoming more and more apparent. Currently, there is a realization that there exists a close connection between these systems, human health, social justice the economy and natural security [6].

2.1.4 Sustainable development

As previously described decisions must be made in society in an attempt to create value, but while doing so difficult problems are faced. In other words from the viewpoint of decision-making sustainability poses a difficult problem [6].

Before continuing it is important to define sustainability. The first definition of sustainability was formed by Hans Carl von Carlowitz when he expressed his concerns about the future of the forests in Europe. The Forester G.L Hartig formulated a definition that is not only applicable in the forestry sector but on all the resources that are available to man: “Every wise forest director has to evaluate the forest stands without losing time, to utilize them to the greatest possible extent, but still in a way that future generations will have at least as much benefit as the living generation [7].”

So from an ecological perspective sustainability is defined as the capacity of ecosystems to be able to continue in its normal functions and process and to preserve biological diversity and not failing in doing so [6].

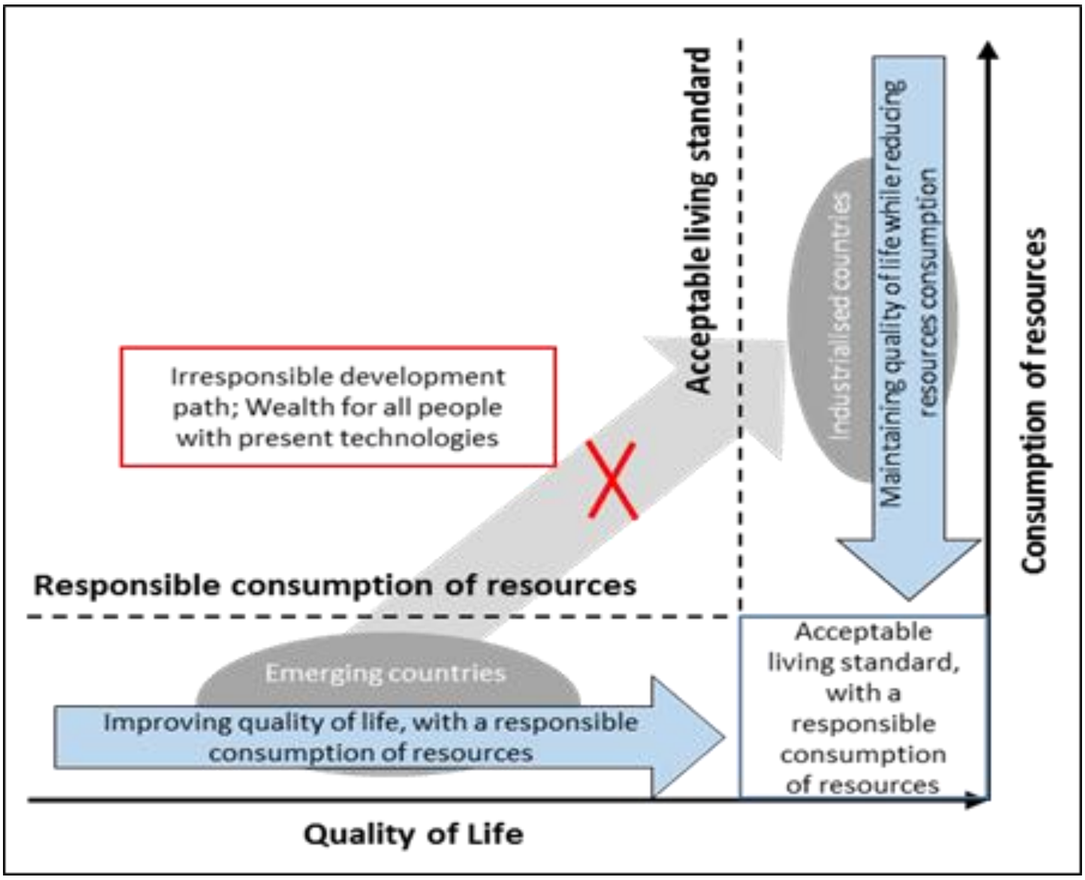


Figure 2-1: The required directions of responsible development (adapted from [5].)

The World Commission on Environment and Development (WCED) declared that the utilization of resources should be in such a manner that future generations will have the same ability to meet their needs as the current generation [8]. Figure 2-1 presents the direction in which sustainable development should go. Emerging countries improve their quality of life with the responsible consumption of resources. Industrialised countries reduces their consumption of resources while maintaining a good quality of life.

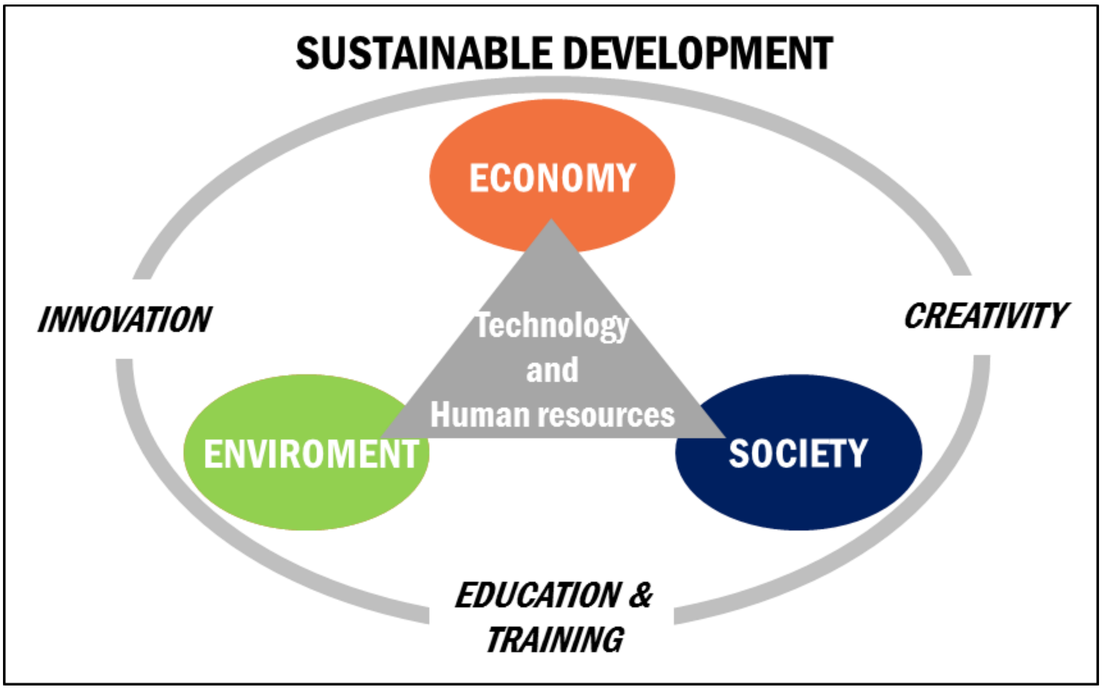


Figure 2-2: The economic, social and environmental nexus of sustainable development, (adapted from [10].)

Westkamper [9] suggests that sustainable development is aimed at improving the living standards of humans while enhancing the availability of ecosystems and natural resources for the coming generations. Sustainable political, economic and social stability can only be reached if human kind as a whole (not only in the first world) can create living conditions and jobs that maintain human dignity. The increase of well-being must benefit the majority of society. Sustainable development must take place within the economic, social and environmental nexus as Figure 2-2 suggests. This requires innovation, creativity and education and training [10].

2.1.5 Sustainable manufacturing

Manufacturing forms the core of an industrialized society [11]. Industry is faced with the challenge of balancing financial and economic priorities against social and environmental responsibilities [12].The US Department of Commerce defines sustainable manufacturing as the creation of manufactured products that use processes that minimize negative environmental impacts and conserve natural resources and energy. It must be safe for the employees, communities, consumers and it must be economically sound [13]. Sustainable manufacturing includes [14]:

- Manufacturing of sustainable products

- The Sustainable manufacturing of all products

The first includes manufacturing of renewable energy, green building, energy efficiency, and other green and social equity-related products. The latter includes sustainable manufacturing as well as considering the full sustainability / total life-cycle issues related to the products manufactured [14].

It is becoming more and more apparent that the global community must establish a recycling society to decrease the impact on the environment. This is accomplished through sustainable development [6]. Jawahir [10] put forth a model for a recycling society which operates in a closed system.

Production systems are usually designed to go from cradle to grave, it is also known as an open loop. Suppliers and customers are involved in the value stream, from the use phase to the disposal phase. In sustainable manufacturing, the loop closes, going from cradle to cradle. The closed-loop system operates on the 6R approach see Figure 2-3, this includes: Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture. Resource consumption is decreased through waste minimization [10].

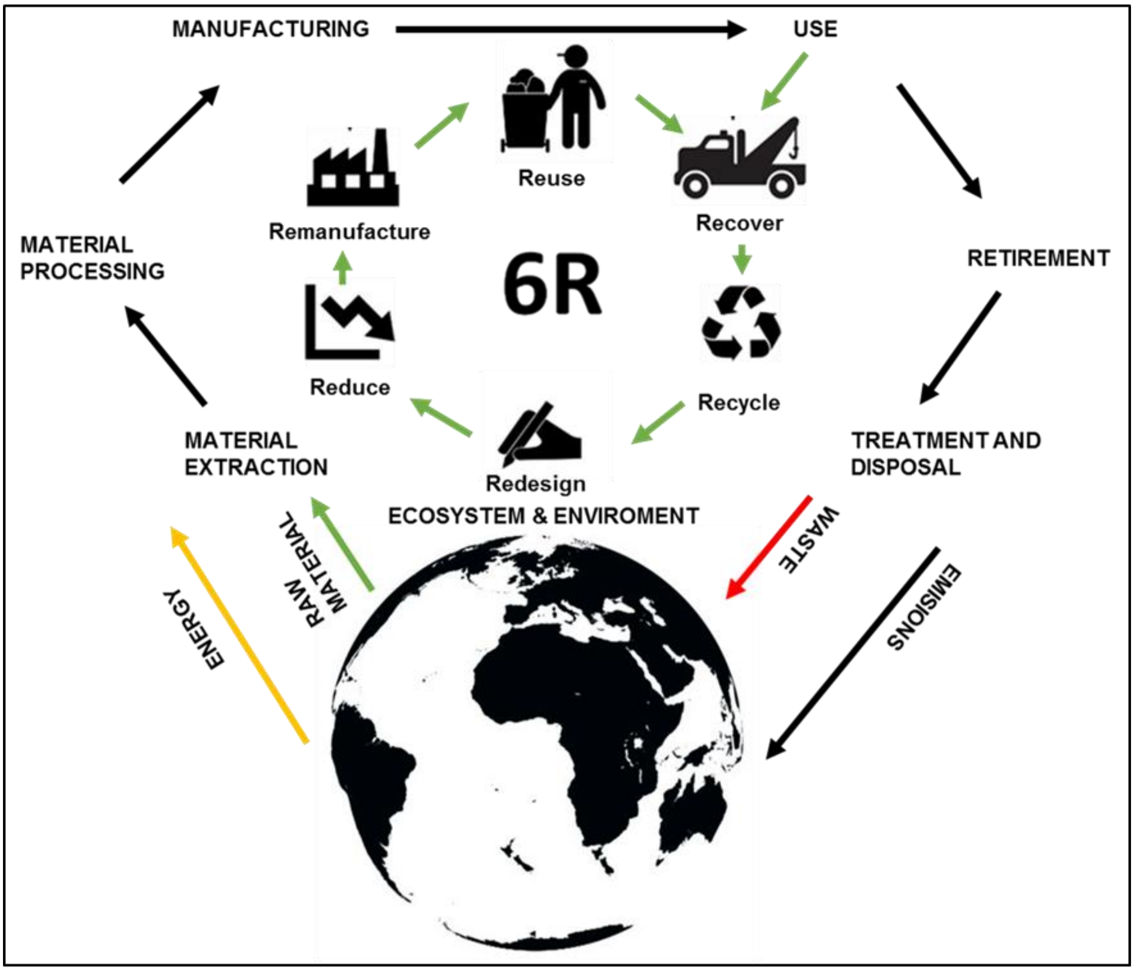


Figure 2-3: The closed-loop production life-cycle system in 6R approach (adapted from [14].)

Recover incorporates the sort, dissembling and cleaning of materials. Product redesign implements design techniques to simplify future post-use processes. Remanufacturing entails the re-processing of a used product for the restoration to its original state or the reuse of its components.

The metric hierarchy house was designed to organize all the sustainable requirements for sustainable manufacturing. The tree pillars of the house are TBL, 6R approach and the total lifecycle focus. The TBL is highly emphasized for general sustainable development, it considers environmental, economic and societal impacts [15]. The total lifecycle approach look at the whole lifecycle as suggested by the name, the 6R process is discussed above. In the centre of the house is the performance measurement framework. The Sus-Prism framework are included here. It is a modification of the Performance Prism framework. This framework is used to assist in performance measurement selection [16].

The two pillars that supports the roof is product metrics and process metrics as manufacturing in its core is creating products through processes. In the middle of the house are the stakeholders [17], the interrelationship between the company and the stakeholders must be analysed. In the roof of the house is the systems metrics which include the line level, plant level, enterprise level and supply chain level. This is an excellent summary of all the aspect to consider for sustainable manufacturing.

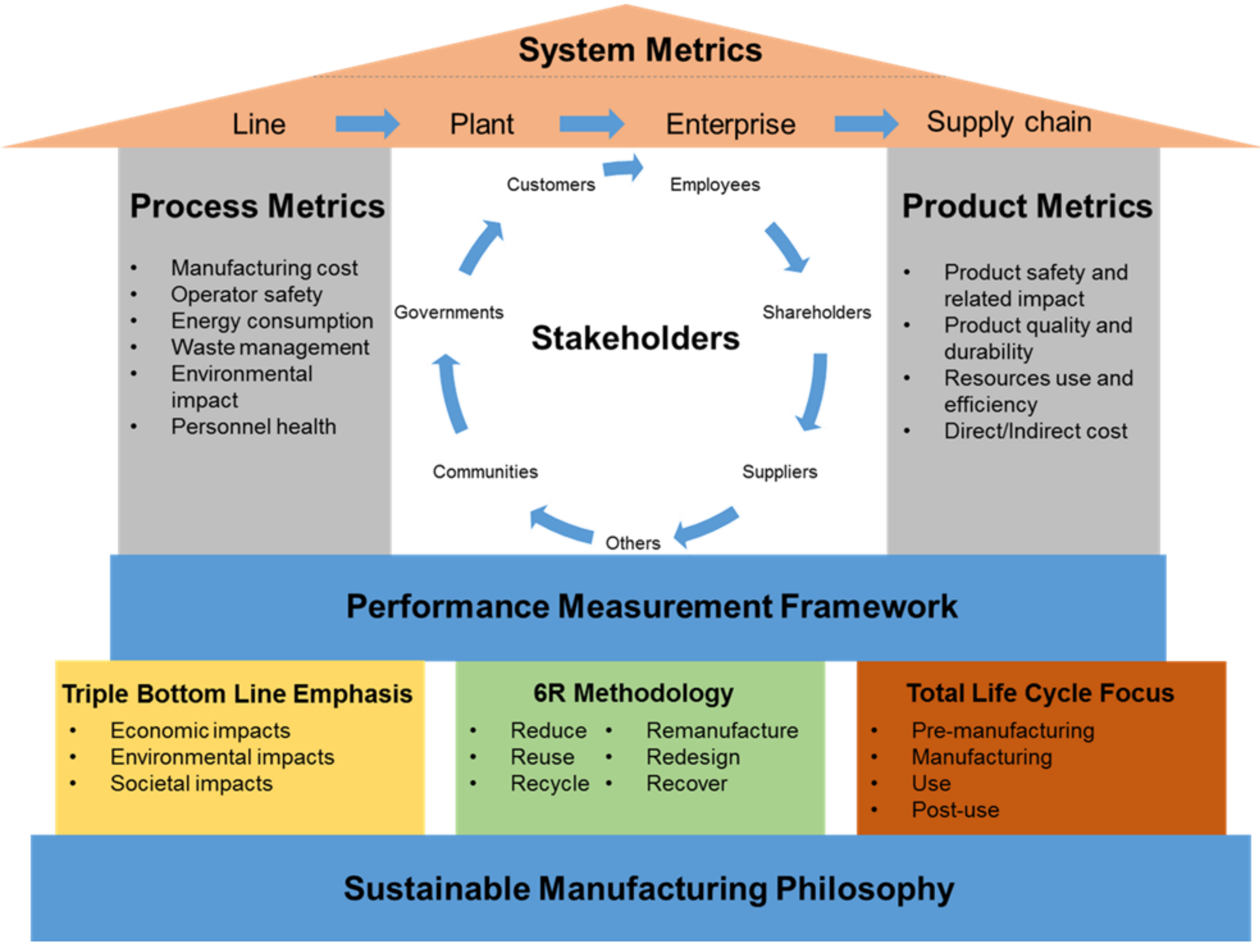


Figure 2-4: Sustainability Performance Measurement House, the product, product and systems level integration (adapted from [17].)

2.2 Bamboo

Bamboo finds its origin in South-East Asia where it is part of the forest ecosystem. There are 1500 bamboo species on the planet most of which are located in South-East Asia. In recent times the plant is gaining popularity. This is due to the easy propagation, vigorous regeneration, rapid growth, high yield and quick maturity. Bamboo is an efficient user of land and produces more biomass per unit area than most tree species. This has only recently led bamboo to be regarded worthwhile enough to be planted as a crop in plantations. The multifunctional range of bamboo applications has also only recently received an increase in attention [18]. Continued technological advancement and research have given bamboo more and more uses and it serves as a raw material for several industries. Bamboo has over 1500 documented applications, which range from medicine, nutrition, toys to aircraft [19]. Figure 2-5 depicts just some of the very basic applications of bamboo produced through traditional and industrial processing.

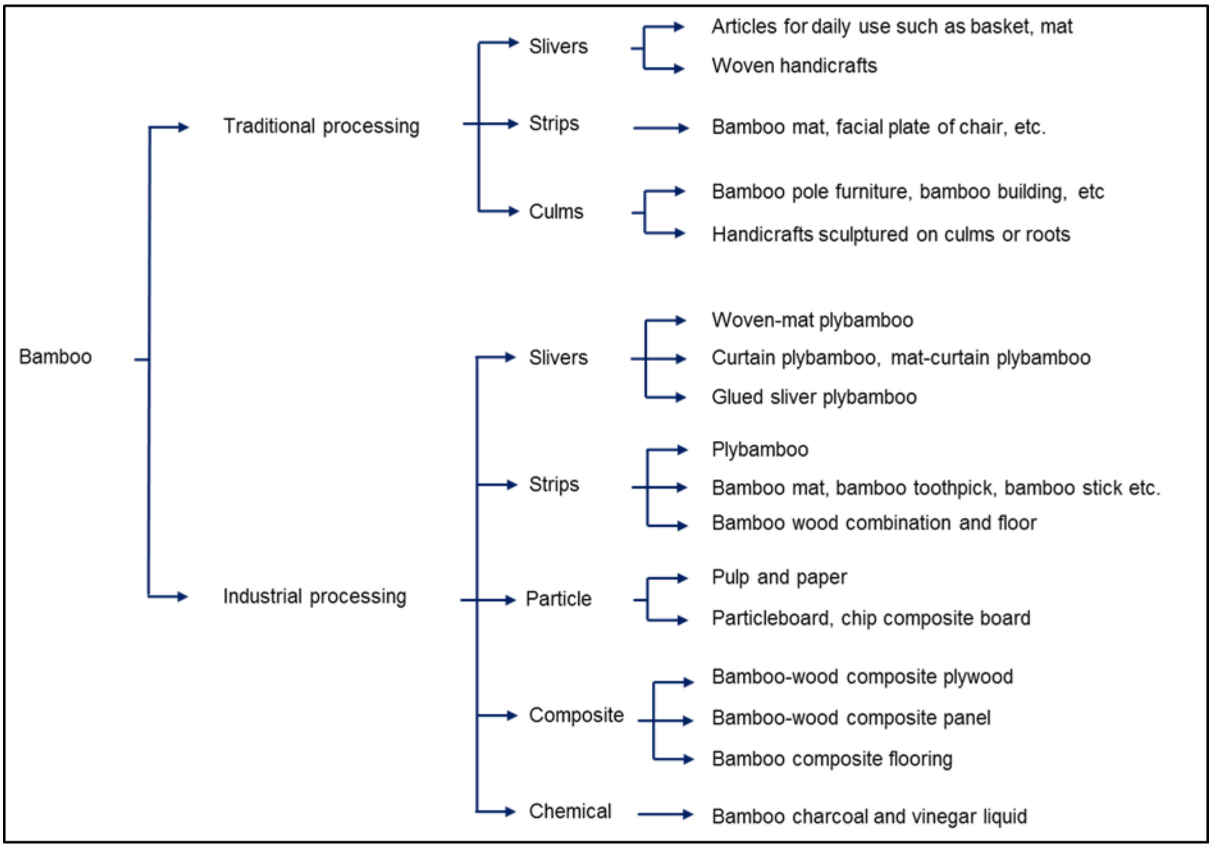


Figure 2-5: The different utilisations of bamboo divided into traditional and industrial processing (adapted from [20].)

Numerous nutritious, active minerals such as vitamins, amino acids, flavine, phenolic acid, polysaccharide, trace elements and steroid can be extracted from the culm, shoot and leafs. All of these have anti-oxidation, anti-aging and anti-bacterial and anti-viral purposes, it goes without saying that it is valuable in health care. To unpack these to the consumer it can be processed into beverages, medicines, pesticides or other household items like toothpaste, soaps, etc. The leaves contain 2% to 5% flavine and phenolic compound. These two components have the ability to remove active oxy-free-radicals, which leads to autoimmune diseases [20], stops sub-nitrification and abating blood fat and it offers possible protection against oxidative damage diseases (strokes and cancers etc. [21]). Some extractions from bamboo are used as a flavor or food storage preservation. Additives obtained from bamboo are used in food such as bamboo juice, beverages and bamboo flavored rice. The bamboo shoot is a one of a kind vegetable, it is low in fat, high in edible fiber and rich in minerals. It removes sputum well, enhances digestion, relieves toxicity, improves diuresis and is also used for treating swollen tissues [19].

The specific gravity, the tension and compression strength of the culm wall increase from the internal inside of the culm to the external side wall of the culm [22]. This means that the area of the culm wall with the lowest strength is the internal third section of the culm. The reason for this behavior is due to the vascular bundles becoming smaller to the outside of the culm wall. Another reason is that the density of the bundles increases when moving from the interior to the exterior section of the bamboo [23]. This phenomena can be seen in Figure 2-6.

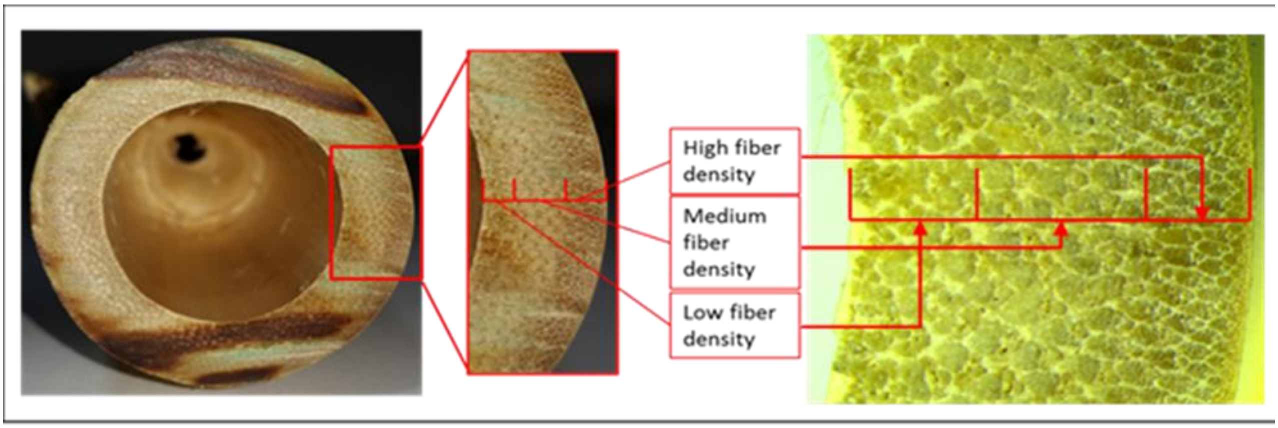


Figure 2-6: This figure displays the difference in density of the culm wall increase from the inside to the outside of the culm [23].

Bamboo is one of the oldest building materials used by man. It is not restricted to geographical area or culture when it comes to the utilization of the plant, be it in urban or rural communities. Bamboo has been used for handicrafts and as a building material in India, China, America and Costa Rica for thousands of years. As a result of unsustainable harvesting, some countries have been forced to restrict the harvesting and exporting of bamboo. For many developing countries this leads to the loss of potential economic opportunities.

According to Salam [19] new terms are used to describe bamboo these days such as “the green gold of the 21st century”, “timber of the future” and “poor man’s timber”. It has played an important part in the human society since time immemorial; currently, it contributes to the subsistence needs of over a billion people globally and plays an important role in the socio-economics of the rural population [3]. Salam [19] claims that the facts prove that the sustainable utilization of bamboo will throw open a plethora of opportunities, especially for the rural poor.

Climate change is another reason for the renewed interest in bamboo. It absorbs carbon dioxide and acts as a carbon sink, while it can also be used as a source of wood energy, thereby reducing the harvesting of indigenous trees. The fact that bamboo can be used to build shelter, reduces deforestation in the communal areas where there is a high demand for indigenous trees especially for building purposes [24]. Liese [25] writes that in the last few decades' bamboo is exploited with renewed interest to serve as a substitute for timber.

Africa desperately needs a substitute for timber. At the end of the 1990's, Africa had an estimated 528 million hectors, 30 percent of the world's tropical forests. Africa loses 4 million hectares of natural forests annually. In several of the sub –Saharan African countries, the rate of deforestation exceeded the global average of 0.8 percent. In other parts of the planet deforestation is mainly due to commercial logging or cattle ranching but in Africa, the causes are associated with human activity. Developing countries rely heavily on wood fuel, the major energy source for cooking and heating in Africa. An estimated 90 percent of the continent's population uses wood for cooking, and in Sub-Saharan Africa, firewood and brush supply approximately 52 percent of all energy sources [26].

In Figure 2-7 some of the advantages of bamboo are summarised: It is a fast grower and has a flexibility [27], it serves as a substitute for most of the applications of wood [28]. Bamboo products are in use by 2.5 billion people on a daily basis [29].It can grow in areas which have marginal soil potential [30] and may even reverse soil degradation [31]. Bamboo has a superior tensile strength compared to wood and steel [32] and most bamboo products are carbon neutral [33].

Figure 2-7: This figure summarises some of the amazing characteristics of bamboo.

2.2.1 Bamboo in South Africa

The only indigenous bamboo in South Africa is *Thamnocalamus tessellatus* [34] and the commercial bamboo forestry sector in South Africa is very small and in an infant stage. EcoPlanet an international company recently planted 360 hectares of bamboo in the Eastern Cape on old pineapple fields [35] and [36]. The total ha of commercial bamboo in South Africa is 692 ha [37]. More than $15 million worth of bamboo products were imported into South Africa and South Africa exported $1.9 million worth of products [38].

The Bamboo source in South Africa that can be utilized is *Bambusa balcooa* this is also the species that were planted at the development mentioned above [39]. *Bambusa balcooa* was introduced to South Africa in the 1660's for paper pulp production and has since been naturalized to South Africa's climate, although its natural habitat is in more tropical climate areas [40]. Isolated bamboo stands as seen in Figure 2-8 a) is a common sight in the Western Cape on Wine farms and in the KwaZulu-Natal province. The companies that manufacture bamboo products in South Africa are just a few, the researcher visited Brightfields a small factory in Cape Town. Figure 2-8 b) displays the raw bamboo stock at Brightfields. The plant itself can reach a height of 12m to 20m and a diameter of 6 cm to 15 cm [41]. In some circles, *Bambusa balcooa* is also referred to as giant bamboo. The characteristics of the *Bambusa balcooa* species will be used as a reference in this thesis as far as possible.

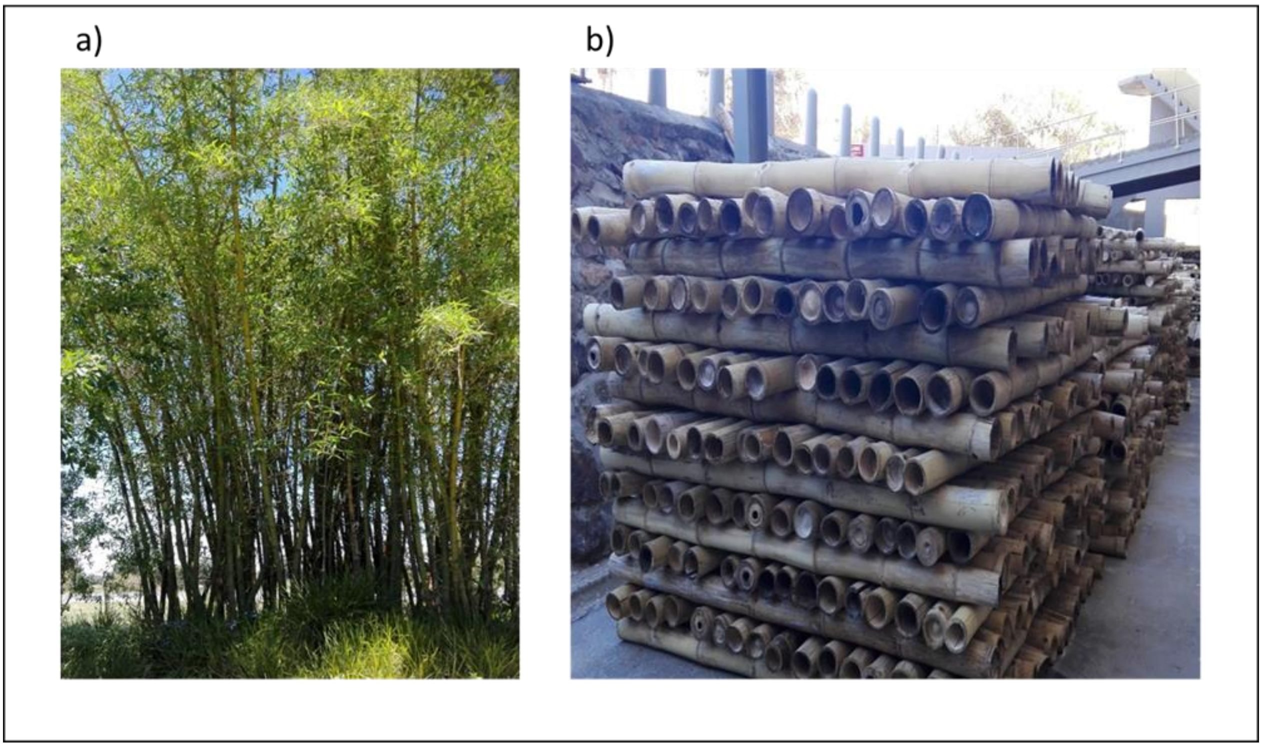


Figure 2-8: Bamboo in South Africa a) is a photograph of a bamboo stand near Riversdal in the Western Cape Province. b) Stacked dried bamboo ready for manufacturing at a small factory in Cape Town.

2.2.2 Applications of Bamboo

2.2.2.1 Food

Bamboo shoots, is an essential food in many Asian countries, such as Japan, Taiwan, Thailand, but especially China. The shoots are offered at a low price and have a high availability. Shoots are low in fat, high in dietary fibre and rich in mineral content [42]. The sprouts are harvested from commercial plantations and natural forests or are even imported to serve the markets. More than 2 million tons of bamboo shoots are consumed per year [43]. These shoots are consumed as a staple food and are mostly sold fresh at markets. Harvesting a sprout means terminating the sprout of the respective culm, hence harvesting must be regulated to avoid the depletion of the entire stand.

2.2.2.2 Paper

Paper is one of the main products that is manufactured from bamboo. For 2000 years bamboo has been used for paper manufacturing in China, It is believed that bamboo paper originated in the time of the Jin Dynasty [44]. In the 5th century AD, the inner parts of the bamboo culm were beaten into a pulp and used for production. More than half of the 3.23 million ton bamboo output in India is used by the paper industry. The present world production of bamboo pulp is roughly 1.5 million air-dry tons of bamboo. The characteristics of bamboo fibres, makes it appropriate for paper pulp production. The fibres are more slender than that of wood fibres, this contributes to the flexibility and smoothness. The high- cellulose content facilitates rayon production as well. Bamboo, however, requires more cooking since it has more impurities than wood [25]. In the past the culms were first crushed then chipped. New mills however only use chippers. The hard and slippery nature of the bamboo culm skin requires special process techniques. The length of the chips should vary between 18-20 mm. In the past pulp mills operated in two stages, during stage 1 a weak alkaline solution removed the low polymer carbohydrates. During stage two it was cooked in a caustic soda and sodium sulphate. Currently pulping is carried out by only cooking [25].

Modern plants cook the pulp at 142-144℃. To produce 1 volume unit of unbleached pulp, two volume units of clean chipped bamboo is needed. To produce 1 volume unit of bleached pulp requires 2.5 volume units of air dry bamboo, or 4 fresh volume units. The bamboo pulp is harder to bleach since chemicals cannot penetrate into the cell lumen, as in soft wood tracheids. This leads to poorer removal of lignin. The quality of bamboo pulp is considered to be relatively good when compared to Kraft soft wood pulp, especially with regards to tearing strength. The tensile and bursting strengths are however lower, but still on the same level as that of hardwood craft pulps. The bamboo pulp is often mixed with pulp from other grasses, bagasse, wood, rag or waste paper [25].

The bamboo pulp is fit for a large variety of paper, for writing, printing, wrapping tissue, etc. The paper quality compares well with conventional paper from wood pulp; it is also used in rayon and cellophane production.

Pulp mills require a large amount of bamboo. In tropical areas, the extraction period is limited to 6-8 months and a stack of bamboo must be maintained for 6 to 9 months. Series damage can be caused by beetle and fungi attack during the storage of bamboo. Common brown rot reduces the pulp yield considerably and the kappa number becomes so high that the pulp becomes hard to bleach. This is as a result of the carbohydrates in the bamboo that is attacked by fungi. This makes bamboo threatened by brown rot fungi unsuitable for pulping. Bamboo affected by white rod, can still be used but it has lower pulp yields, with a lower physical strength and a greater need for bleaching chemicals. In a 12 month storage period, about 20-25% of bamboo can be destroyed by organisms that attack wood. The storage loss can, however, be reduced by preservative treatment, sufficient drainage, aeration and the limitation of the stack sizes. The stored culms, should not be in contact with any soil, and fire precaution is a necessity, at these kind of facilities [25].

2.2.2.3 Bamboo vinegar

Bamboo vinegar is a transparent brown-red liquid produced during the pyrolysis of bamboo charcoal [45] and contains more than 200 types of chemical components [46]. The smoke that escapes condenses in the vents of the oven and drips into a receptacle. The condensate which appears dark brown smells smoky and separates into a yellow layer- the vinegar, and the bottom layer- bamboo tar. Depending on the type of bamboo and temperature, the condensed vinegar contains more than 200 organic substances. The premier percentage of vinegar acid is produced at an abstraction temperature of 300℃, at this temperature it has a pH, of 1.8 and an acid content of 8.7 %. Because of the low pH it is used to acidify alkaline soil, it is also a component in various medical products. It is used in the cosmetic industries and it’s used as an antimicrobial [25].

2.2.2.4 Biochar

Biochar is produced specifically for application to the soil as part of agronomic or environmental management. In 2012 the International Biochar Initiative (IBI) was the first to formally define it as: Biochar that is used in soil [47] and to describe the characteristics that differentiate it from other carbonaceous products. Figure 2-9 illustrates the basics of Biochar production.

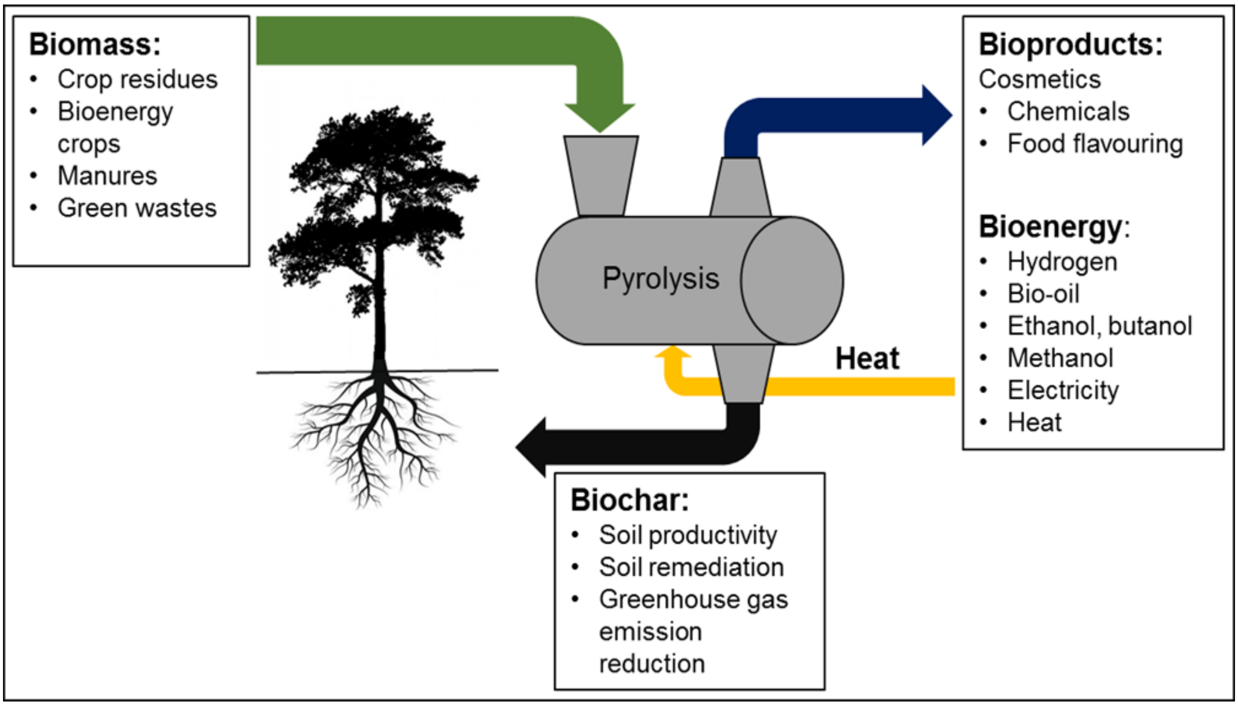


Figure 2-9: A basic schematic diagram displaying the inputs and outputs in the Biochar production process (adapted from [48].)

During pyrolysis, the cellulose, hemicellulose, and lignin which is the building blocks of the biomass undergo numerous processes such as cross-linking, depolymerisation and fragmentation at various temperatures. The main products of the biomass pyrolysis are condensable (tars) and non-condensable volatiles and char. The condensable volatiles are liquids and the non-condensable volatiles are gases such as carbon monoxide (CO), hydrogen (H_2) carbon dioxide (CO_2) and C_1 –C_2 hydrocarbons. The product yields depend on the following factors:

- The composition of feedstock's specifically the lignin and the ash content.
- The temperature of the process
- The pressure during the process
- The vapour residence time during the process
- The heating rate in the process
- Particle size
- Heat integration

Table 2-1 displays the typical yields in the pyrolysis of wood in different modes. Note that gasification follows the pyrolysis process.

Table 2-1: Displays the different products obtained with different pyrolysis conditions [48].

Mode	Condition	Liquid (bio-oil)	Solid (biochar)	Gas (Syngas)
Fast pyrolysis	Moderate temperature (~500˚C) Short Vapour residence time.	75% (25% water)	12%	13%
Intermediate pyrolysis	Low-moderate-temperature Moderate hot vapour residence time.	50% (50% water)	25%	25%
Slow pyrolysis	Low-moderate temperature time	30% (70% water)	35%	35%
Gasification	High temperature (>800˚C) Long vapour residence time	5% tar (55% water)	10%	85%

The production of biochar can be classified into two sections; batch and continuous processes, Figure 2-10 displays a typical biochar production process.

Batch processing is the traditional way of producing charcoal and includes the use of earth mounds, pits, and metal and brick kilns. This is very simple and cheap technology, however, it is quite inefficient. It is known to produce low yields, it has no recovery of heat and it has a significant feedstock burn off.

Continuous processes are associated with higher yields compared to batch processes. There are three main continuous process techniques.

The first is drum pyrolysis, in the drum pyrolysis process, the biomass pass through a horizontal cylindrical tube with the help of paddles before it enters the drum. This results in good biochar and gas quality. No air is introduced by intention, however some may enter the process in the voids between the feedstock. The gas is used in the firebox to heat the biomass to pyrolysis temperature. Drum pyrolysis is seen as slow pyrolysis as it takes several minutes for the biomass to travel through the drum, its production time is still short in comparison with batch processing.

In the Screw type pyrolysis process, the second method, the biomass is moved through the reactor by means of a rotating screw. It can either be heated externally or a heat carrier such as sand can be used to heat the biomass as it is conveyed through the tube. This process can be conducted on a relatively small scale, it uses a variety of feedstock and produces high yields. Heat and energy generation can be integrated into the process.

The third method is by means of rotary kilns and it can be classified as direct or indirect drum kilns and depends on the heat source which can even include electricity. It can operate at capacities of up to 1 ton per hour. The sizes may vary and lengths of 4 – 12 m has been reported, while diameters of 0.3 m to 1 m have been reported. The temperatures can also range from 150 -1500 ˚C [48].

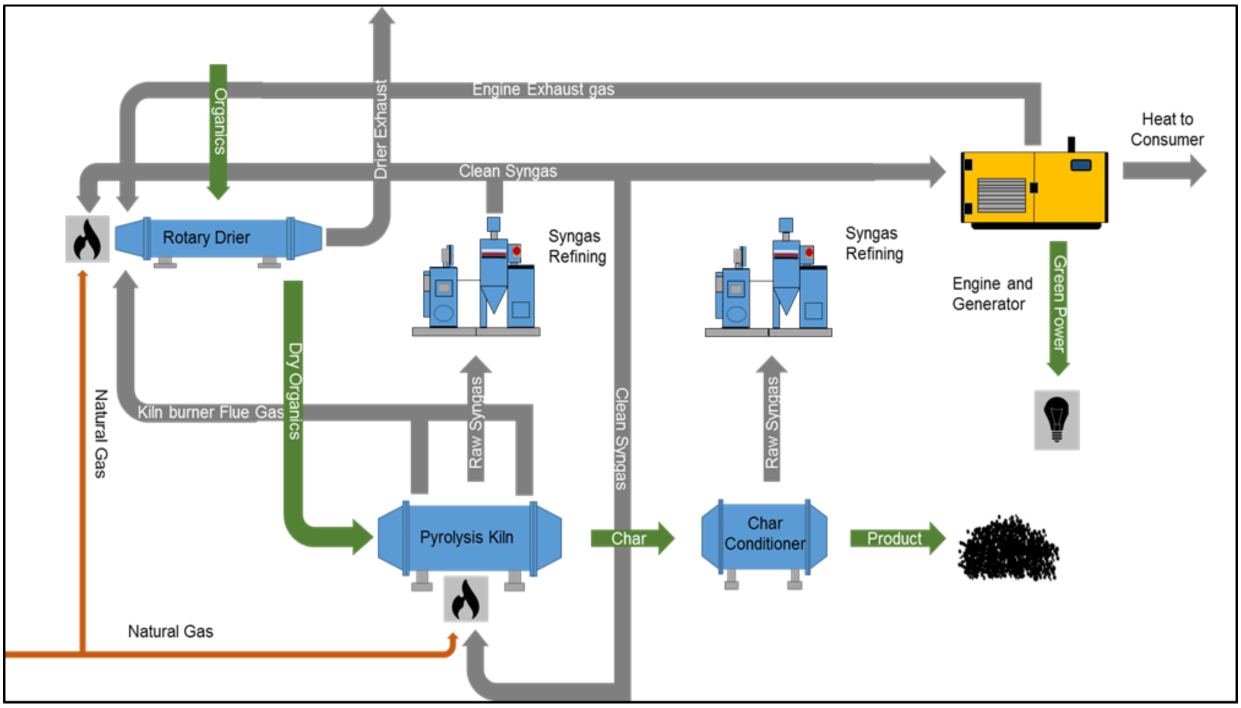


Figure 2-10: A basic schematic diagram displaying the inputs and outputs in the biochar production process (adapted from [48].)

Slow and intermediate pyrolysis results in high biochar yields, while fast pyrolysis leads to higher liquid yields. Thus to ensure high biochar yields slow and intermediate pyrolysis must be pursued. The following conditions lead to higher biochar yields:

- If the biomass has a high lignin, ash and nitrogen content.
- Low pyrolysis temperature (According to [48] the temperature must be < 400 ˚C), this contradicts the prescribed temperature range suggest by NewCarbon [49].
- High process pressure
- Long vapour residence time
- Extended vapour solid contact
- Low heating rate
- If the biomass has a large particle size
- If it is operated at an optimised heat integration.

The feedstock characteristics and the pyrolysis condition are detrimental to the physical and chemical properties of the biochar and its application. Biochar comprises of multiple elements and counter to popular belief does not only consist of pure carbon only. The element composition includes carbon (C), oxygen (O), hydrogen (H), sulphur (S), nitrogen (N) and ash [48].

i The benefits of using biochar

Biochar is applied to soil as certain advantages have been observed as a result of this. It adds value to the agricultural sector by augmenting the soil's water holding capacity and nutrient retention ability. It leads to long term carbon sequestration and inhibits the release of GHG emissions. This includes the release of nitrous oxide (N_2O) and methane (CH_4).

In addition to the above-mentioned advantages, biochar is also receiving interest due to its agronomic benefits. It is reported that biochar has the potential to increase the pH of the soil, decrease aluminium toxicity and decrease the tensile strength of soil. Biochar is recounted to enhance the soil condition for earth worm populations. Last and certainly not least, the use of biochar in combination with inorganic fertilizer can increase crop productivity, providing more income to the farmer while reducing the quantity of inorganic fertilizer required [48].

It must be mentioned that if biochar is sold as a soil amendment and marketed as a compost or fertilizer, it will need to be registered under the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act (Act No. 49 of 1996), Regulations Regarding Fertilizers (Republic of South Africa, 2012). The regulations do not specifically make reference to char, biochar or carbon as a soil amendment, but if biochar is to be sold under any of the product names defined in the regulations, it will need to meet specific requirements[50].

ii The relevance to Africa

In Sub-Saharan Africa (SSA) the drastic decline in soil fertility is attributed to constant cultivation in combination with organic matter mineralisation. The above mentioned, high soil acidity and the presence of highly weathered secondary minerals have been identified as the major cause of food insecurity and poverty in SSA. Another phenomena that has a direct negative effect on the crop productivity and percussion on the economy is soil erosion. This degradation has led to irrigated lands in SSA countries producing only 7 % of its potential. Crop plants dependant on rain are reported to produce between 14% and 45% below their potential productivity.

2.2.2.5 Bamboo Charcoal

Bamboo is a very important source of energy for heating and cooking in many tropical and subtropical regions. The raw culms are not good combustible materials on their own, for three reasons: It does not store well, burns fast and produces a thick smoke. Converting bamboo to charcoal deals with this. In China charcoal has been produced and utilised for over a 1000 years, and exported in either its basic form or as various manufactured products[25]. The production and the use of bamboo charcoal and its by-products is promoted by several international organisations such as INBAR (International Network for Bamboo and Rattan) and ITTO (International Tropical Timber

Organization). The European Union and INBAR both support the utilization of bamboo charcoal instead of wood in Ghana and Ethiopia. A four-year program ran from 2009-2013 amounting to a cost of 1.3 million Euro to facilitate this [25].

Figure 2-11: Bamboo and bamboo charcoal briquettes produced by Brightfields in CapeTown.

Bamboo is referred to as black bamboo in Asia. The charcoal is available as culm segment, or as a chunk, compressed into briquettes (see Figure 2-11 above) or in a granular or powder form. In its basic form, it is used for cooking, heating and smoke-free grilling. Much of it is processed further into multiple products [25].

i The difference between Biochar and Charcoal

It is essential to distinguish biochar, char and charcoal from each other. These tree products, known as carbonaceous material are all produced by means of pyrolysis. Pyrolysis includes the heating of carbon (C) bearing material in an oxygen (O_2) starved condition. Char is defined as any carbonaceous residue from pyrolysis, this includes natural fires. Char is the general term when referring to products of pyrolysis and fires whether the source is biomass or other materials.

The term charcoal refers to char produced in kilns through pyrolysis of vegetable or animal matter for use in cooking and heating. There are certain factors in the manufacturing process that cause a significant difference in the product, and which differentiates Biochar and Charcoal from one another. According to Van der Merwe [49] founder of NewCarbon, a South African based company, Biochar has a higher carbon content than Charcoal. The Carbon content of charcoal ranges between 70-80% while the carbon content of Biochar varies between 85%-95%. Charcoal is produced between

400-450˚C and Biochar is produced between 550-900˚C. In the Charcoal production process, a great amount of Polycyclic Hydrocarbons (PAH's) are produced. These are not produced in the Biochar production process.

ii The traditional production process

Bamboo charcoal is black and light in weight comes from the pyrolysis of bamboo. The bamboo biomass is heated intensely in an oven without oxygen, the oxygen is first controlled and then latter completely turned off. During this process, the culms release intrinsic water and volatile components. The end products of the process is 30% bamboo charcoal, 51% bamboo vinegar, 18% bamboo gas and 1% waste [51].

Bamboo charcoal is mostly produced from moso bamboo [52] (*Phyllostacus edulis*) in China and the production process are as follow: The culms are harvested when the culms are at least 4 years old. At this age the fibre has hardened to the point that it is suitable for industrial production. The culms are felled and cut to lengths of 80-120 cm, quartered and air dried for weeks to several months, to the point of shrinkage from dehydration. The sticks are then exposed to 180-200℃ for 6-10h in an industrial dehydrator. The dehydration brings the water content to 15-20%. In charcoal production the moisture content of the bamboo is an important factor to consider. It affects the quality of the charcoal. According to Liese [25] the moisture content of bamboo is brought down to 15% to 20% before it is used for charcoal production. The National Mission on Bamboo Applications [53] states that the best moisture content is between 20% - 25%, but later it is mentioned the moisture content should be around 15% to 20%, and if the moisture content is higher the yield reduces. For this this study the interval of 15% to 20% will be used and the middle of the interval which is 17.5% will be used for calculations.

In small rural operations, kilns are used instead of these specialized dehydrators, the bamboo is directly processed into charcoal in these operations. Ovens differ depending on the availability of bamboo culms, the financial circumstances, and the local conditions. Traditionally mud ovens are used by rural people and they have a heat-resistant shell with slanting pipes branching out. Vinegar is condensed in these pipes from the vapour and collected in containers, see section 2.2.2.3. If the production exceeds local needs and the financial means are available, the production takes place in iron ovens, which can support a small industry. The big industrial charcoal production sector uses ovens that are continuously fed with raw materials sourced from a large area [25].

Table 2-2: Yield rate and ash content at different temperatures [25].

Item of properties	Carbonization temperature T [C˚]							
	300	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
Yield rate (%)	40.70	35.6	29.68	28.96	27.52	27.43	26.39	26.69
Ash (%)	2.93	3.48	3.54	3.92	4.07	4.58	4.69	4.57

The process in the oven are as follow: The pieces of bamboo are stacked in the oven at the right angles. The mouth of the oven is then closed with stones and mud and the oven is stocked with wood or bamboo. The air exhausts at the top opening. This opening is later closed and small openings are left at the sides to allow air circulation. As the process progresses, these openings are also closed. When the charcoal starts forming, individual openings are broken open to control the vertical and horizontal airflow. This ensures a universal conversion to charcoal. The temperature should be maintained between 500℃ and 600℃. Lower temperatures result in an incomplete conversion to charcoal or the biomass burns to ash, Table 2-2 displays the yield and ash content at different temperatures. After two days all the openings are closed so that no fresh air can enter the burn chamber, it is left to cool down for one additional day after this. The charcoal and ash are removed and the oven is ready for reuse after it is cleaned. This method gives a yield of about 30% of the dry initial weight of the culms used [25]. In the pyrolysis of bamboo, 7% gas is produced, the most notable are carbon dioxide, carbon monoxide, methane, ethylene, and hydrogen. This mixture of gas is used directly as fuel. The remaining 2 – 4 % ash contains minerals such as silica, calcium, potassium, magnesium, sodium, iron and manganese. The ash is used for agricultural purposes as a fertilizer and for acidifying soil [25]. The bamboo should not be harvested within 7 days of carbonization. This will improve the yield [54].

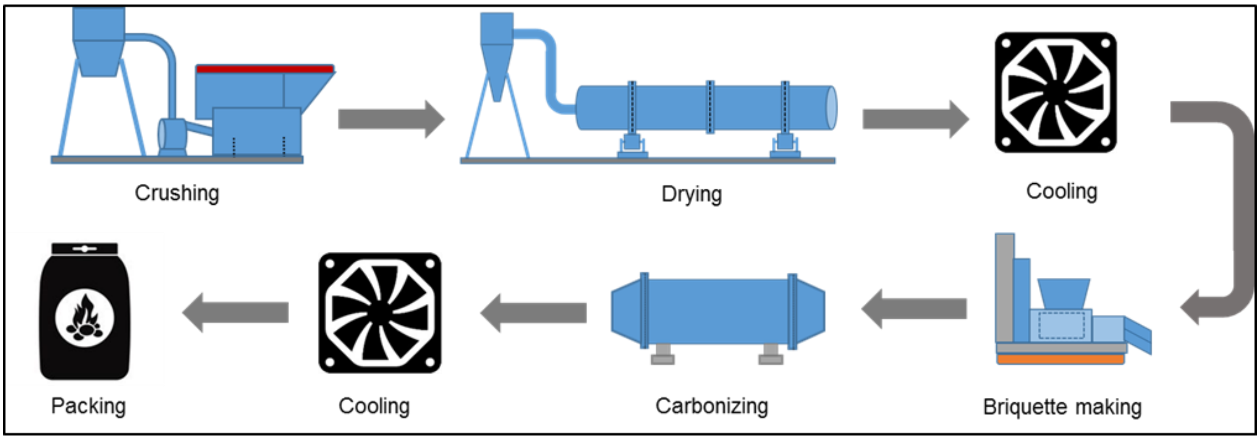


Figure 2-12: A typical charcoal production process (adapted from [103].)

No machinery is necessary for the construction of a mud oven and it can be done by experienced villagers. It is a challenge to control the temperature and to keep it evenly high since the pyrolysis temperature is evenly high. If the temperature control is faulty it could lead to cracks in the wall of the oven leading to the oven exploding or breaking apart. Iron ovens are often fitted with an integrated dehydrator and it is a lot easier to reach and control the temperatures required for carbonization. This facilitates the steady rise in temperature which is required for the production and which allows a higher throughput. The air circulation and carbonization temperature is also easier to control, which assures that a higher a carbon content can be reached. In the end it improves the quality of the charcoal and better separation in the gas and vinegar [25].

iii The industrial processing

Figure 2-12 displays a typical industrial production process, some of the most common methods used in the industrial production of bamboo utilises an oven with a conveyor belt or one that rotates. Through the continuous use of an extrusion press, a large quantity of bamboo charcoal can be produced. The culms are fragmented into chips, this breaks the hard outer epidermis [25].

In Thailand compressed charcoal are made by grinding charcoal pieces. Water and an adhesive are added and this mixture is then compressed six-sided cubes and dried. This compressed bamboo is extremely hard with fine pores, it promotes sustained burning with a high heat. The hexagonal shape benefits shipping, since the honey comb is highly stable, this ensures little breakage and minimizes packing space. These ovens have a high acquisition and maintenance cost. Hence these ovens are only used for mass production of charcoal when the raw material is harvested regionally and supplemented by industrial scraps [25].

iv Quality control

There exists no international standards for the quality of bamboo charcoal. However, factors such as the raw density hardness, electrical resistance etc. make bamboo charcoal comparable to many wooden types. The “Hardgrove-Index” functions as some measure of hardness by grinding; A smaller index value indicates a harder charcoal and vice versa. Industrial analysis inspects different character, which includes the moisture content, ash, volatile components and fixed carbon [25].

v The properties of bamboo charcoal

When looking at the uses and properties of bamboo charcoal, mention must be made of China. In China, the properties, preparation and possible uses has long been studied. The manufacturing process as well multiple products and their uses have been documented over ages and are on display for the public in the museum of bamboo charcoal in Zhejiang province in China. The bamboo charcoal market in China today is still alive [25].

Bamboo charcoal consists of 85% carbon, 7% gas and 2% to 4% ash. The pH is influenced by the carbonization temperature and is usually above 7.0 if the temperature is above 600℃. It is mostly used as a combustible material due to its high heat value, and it not vulnerable to fungal or termite attack [25]

The heat value is an important indication of charcoal’s energy storage, at a combustion temperature of 500-800℃ it ranges from 7400-8000 Kcal (31-33) MJ wood charcoal has a value of 7000-7800Kcal (29-33) MJ. It has an average burning time of 4 hours, which makes it suitable for the use in a fireplace [25].

Bamboo charcoal (200-300 m^2/gram) [55] has a surface area ten times greater than that of wood charcoal (30 m^2/gram), this makes it a good absorbent material [56].This high absorptive property is utilized in various ways. It can absorb harmful substances from the air [57] such as formaldehyde, ammonia, and benzene. The high porosity of bamboo charcoal binds with moisture from the humid air and releases it with decreasing humidity. Areas which harbour this application of bamboo charcoal include bathrooms, bedrooms, as well as pillows and bedding. It is not unusual to mix it into walls, floors and under houses. Pounded charcoal is combined into paper bags, pillows and mattresses and it is woven into the outer wear [25].

Bamboo charcoal binds with dangerous substances such as carbon monoxide, benzopyrene, carbon dioxide and nicotine and tar. In China, the cigarettes filters contain bamboo charcoal and absorbs 95% of the toxic substances. Ethylene produced by fruit and vegetables refrigerators are bound by charcoal, enhancing the life of the produce in the refrigerator. The same can be applied to fish and meat odours in refrigerators. Last but not the least it is also used to control body odours, in the form of shoe inserts and in additive soaps [25].

2.2.2.6 Activated carbon

Activated Carbon is a term used to define carbon-based materials which has a well-developed internal pore structure [58]. It is produced from a range of carbonaceous rich materials such as wood, coal, lignite, coconut shell and bamboo [59]. The high surface area [60], large porosity well-developed internal pore structure comprising of micro- meso- and macro pores and large spectrum of functional groups on the surface, makes it a versatile material. Activated carbon is an essential component of filter material used to remove hazardous components in exhaust gases, to purify drinking water and to treat waste water [61]. Ghauri et al. [62] is of the opinion that the demand for activated carbon will keep on increasing as a result of its wide range of applications and due to environmental compliances in several countries. The biomass used to produce activated carbon are usually by-products or waste materials in commercial activities.

Bamboo can also be converted into activated carbon, following the carbonization process discussed above. The bamboo char / charcoal goes through an activation process. The process of activation can either be done by steam or chemical activation [63]. The carbon content is enriched in the carbonization process and porosity is created. The carbonized raw material of the activated carbon process is done at a temperature in the range of 300-400˚C. Carbonisation gasses are produced during the process. It can be classified as gasses and oils (tars) when it is cooled to the surrounding temperature. The charcoal, which is the residue of the carbonisation process, is the primary material for the activation step. In the activation step, the charcoal is activated by steam in the same reactor at a temperature of 650-800 ˚C. This leads to more pores being created as the carbon is oxidised [62]. Figure 2-13 displays a typical activated carbon production process, by means of steam activation.

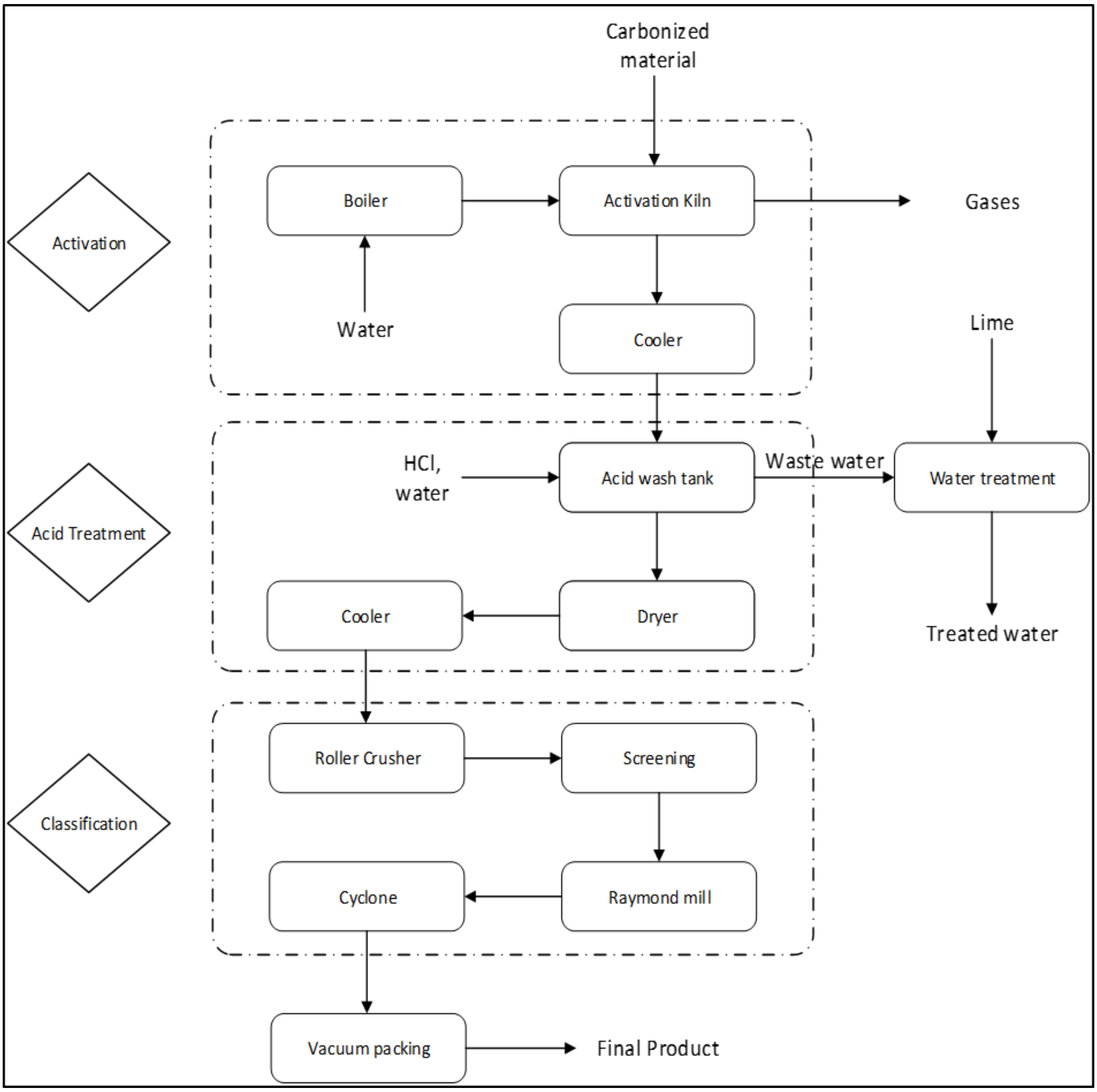


Figure 2-13: A typical Activated Carbon production process through steam activation (adapted from [64].)

The required specifications from the customers can be met by making certain adjustments to the system. These adjustments include the rotating speed of the activation kiln and the steam temperature. The required specifications of Activated Carbon for air pollution control and water treatment varies greatly. The former emphasizes more on the iodine value and the latter on the methylene blue. If the Activated carbon is to be used in the pharmaceutical industry the focus would be the Fe, Cl and bacteria content.

Choy [64] describes the chemical activation process in more detail. The bamboo is crushed into smaller particles to benefit the carbonization process. The granular bamboo is then impregnated with potassium hydroxide (KOH) which aids in the chemical activation process. It is then heated in an oven at 110 ˚C for 8h to evaporate the chemical solution and to remove water. The bamboo treated with alkaline is conveyed to a carbonization furnace operating at 850 ˚C in the absence of air. Nitrogen is used in the purging process to deliver an oxygen-free environment for carbonization to take place. There is a stream of gas leaving the carbonization furnace. These volatile gasses usually consist of carbon dioxide and monoxide, hydrogen, some light hydro carbons and methane. These gasses have a high energy content and are channelled and used as fuel to generate heat in the combustion process.

The carbonization process described by Choy [64] yielded 20-24% activated carbon. After the product is cooled it is washed with water to remove the KOH. The KOH is reused in the next batch of bamboo. The produced activated carbon is moved to the storage tank for packaging and delivery. The remaining volatile gases are fed into the combustion chamber. A temperature of 1000˚C is maintained in the combustion chamber and the outlet chamber is so intensively high that the dioxin is destroyed. The flue gas leaving the combustion chamber flows into a steam boiler for energy recovery and electricity is generated. The flue gas leaving the heat exchanger enters the lime scrubber where HCl and SO is removed. The emissions are monitored continuously to ensure that the gas emission does not exceed the government limits.

2.2.2.7 Bamboo Laminated board

It is not fairly difficult to utilise bamboo as a construction material in its natural cylindrical state. Creating reliable connections, however possess a challenge, due to the geometry and the fact that bamboo is prone to splitting. Bamboo is also not perfectly straight with a non-uniform cross-section. Its cylindrical structure means that it is inefficient space wise.

A relatively new concept called laminated bamboo lumber or also known as laminated bamboo board is a lumber-like product produced from bamboo [65]. The bamboo culm is disassembled into thin flat laminae and then glued together in a range of orientations to from a certifiable structural member [66]. The product of this process is rectangular boards or beams, which is characteristically similar to that of lumber. There are three distinctively different processes in producing laminated bamboo lumber (LBL) [67]. Figure 2-14 is a detail depiction of a common production process.

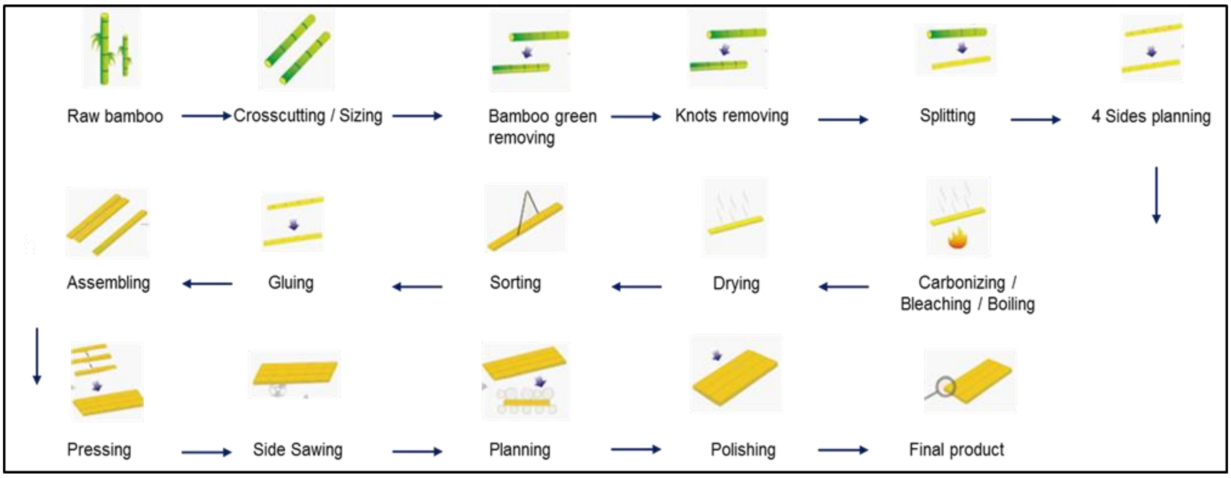


Figure 2-14: Laminated bamboo board process (reworked from [69], [20] and [70].)

In the first method, bamboo culms are crushed by means of a roller press to create zephyr strand mats. The mats are hot-pressed at temperatures between 150 to 180 ˚C, this aids in obtaining a smoother surface, and it increases dimensional stability. Dipping the mats in boiling water flattens the fibres. After this process, the mats are passed through a planer that removes the outer and inner layers that contain silica and wax and that weakens the adhesive bonding. The mats are then coated with resorcinol-based adhesive and piled on each other. The inter bonds are optimal when joining the outer to inner surfaces and with a glue spread of approximately 300 g/m^2. The stacks of mats are cold pressed and the mats are stored at 25˚C with a relative humidity of 65% for at least 2 weeks [67].

In the second method, the culms are fed through a splitter machine which cuts the bamboo culms into slender strips, Figure 2-15 depicts this transformation. All the surfaces of the strips are planed to remove silica and wax and to produce a neat rectangle shape in the cross-section. The strips are left for one week to air dry. The air dried strips are submerged in a boron solution and then placed in the sun to dry. When the strips reach a 12% moisture content they are placed side by side and edge glued using tannin resorcinol formaldehyde, extracted from *Acacia mangium willd* (black wattle) bark and mixed with wheat flour. The sheets are then placed on top of each other and the grains are kept parallel. The strips can be stacked in different orientations as can be seen from Figure 2-17. The same adhesive is used and it is clamped for 4 hours and no heat is used [67].

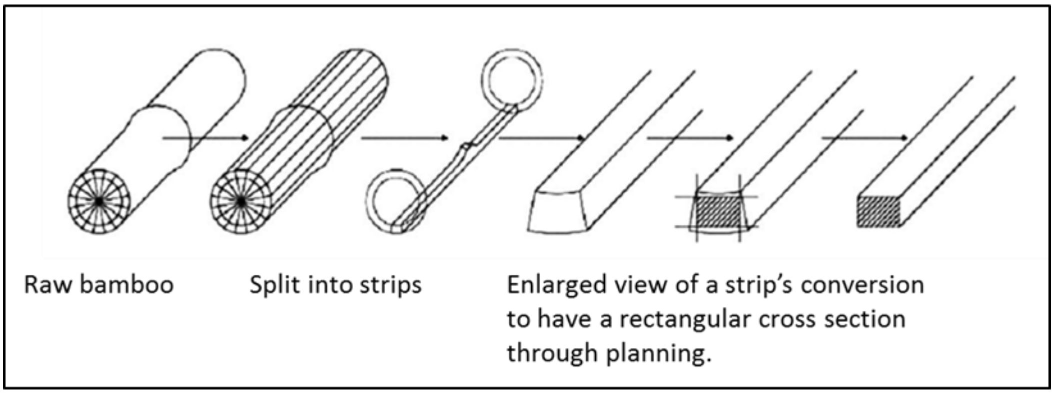


Figure 2-15: From culm to strip, that basis of laminated bamboo board, (adapted from [67].)

The 3rd method starts by splitting the bamboo in half in the longitudinal direction. The splits are then flattened for 1-4 min at a pressure of 690 kPa. The time required to flatten the bamboo is determined by the thickness and curvature of the bamboo splits. The flattened bamboo are then passed through a planer to remove all the silica and wax. An adhesive that is resorcinol-based, is applied to the surfaces of the flattened and planed bamboo splits and they are then stacked on top of one another. The stacked bamboo are placed on top of each other and compressed at a pressure of 1380 kPa for 12 hours. The final product is stored at a 65% relative humidity at 25 ˚C and for at least two weeks for final conditioning.

Bambusa Balcooa culms can be up to 24 m or even 30 m tall according to The National Mission of Bamboo applications [69], but it is more common for the culms to be 18 m tall [70]. Sharma et al. [68] estimated that only 30% of the bamboo culm eventually become the laminated bamboo board, see Figure 2-16.

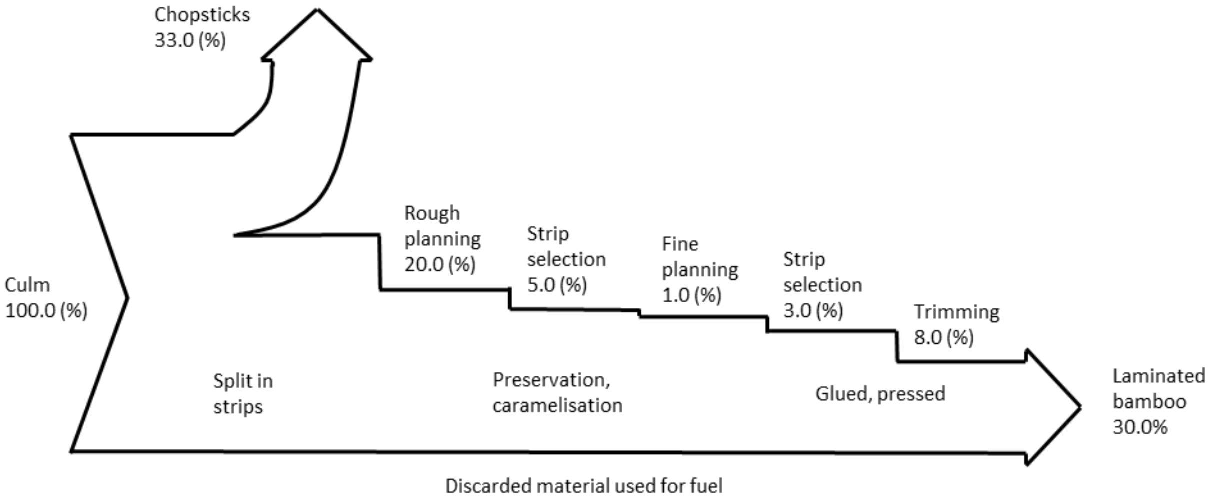


Figure 2-16: The picture illustrates that only 30% of the original culm weight is used in the board production (adapted from [68].)

Figure 2-17: Two laminated specimens: The different orientations can be witnessed from a side view and top view of each specimen.

To compare the mechanical properties of LBL with structural commercial lumber products, laboratory tests were done. Two lumber specimens were used. Eastern Species laminated veneer lumber (LVL) and Eastern Species PSL, manufactured by iLevel. Specimens were of length 2.5 x 2.5 x 40.6 cm^3 and were tested in a three-point flexure. The LBL specimen was produced using method three as discussed above. The specimens were tested in the vertical lamination orientation. The tests were configured using a 150 kN capacity MTS universal testing machine. The load was applied under a displacement control rate of 1.3 mm/min to achieve failure in 5 to 8 minutes. The Specimens had a moisture content of approximately 6% and were conditioned to the laboratory relative humidity and temperature. The LBL specimen had a moisture content of 10% and a glue spread rate of 420 g/m^2. The difference in moisture content may have had an effect on the outcome, Mahdavi et al. [67], is of the opinion that Wood would have had slightly lower values if that was the case. LBL has a bending strength that is respectively 18.7% and 14.7 % higher than PSL and LVL. The stiffness of LBL is lower than that of PSL and LVL by 27.5% and 21% respectively.

i Summery

Considering bamboo's mechanical and physical properties, bamboo can compete with other structural materials. Mahdavi et al. [67] is of the opinion that the strong barrier to the commercial success of bamboo is its cost. In a study done in 2007 it was concluded that the reported price of LBL can be four times that of conventional lumber, and 1.6 that of glue-laminated lumber. That was in 2007, 10 years later things may look significantly different. There are several companies that are emerging and that are producing LBL that is economically viable. A Chinese company called Advanced Bamboo Technologies developed a LBL product called Glubam which competes with dimensional lumber. In China, it has been used in residential applications as beams and columns. Cali Bamboo a U.S company has introduced a laminated product for posts and rails with dimensions up to 3 in. x 3 in. x 10 ft. From a production point of view, bamboo produces three times more biomass than the average productive timber forest. Hence its quick growth and high strength-to-weight ratio means that it could be key in the sustainability movement.

2.3 Financial modelling

2.3.1 Introduction

This chapter is devoted to realising the economic feasibility of manufacturing each bamboo product. According to [71] an economic financial feasibility study consists of 11 pieces of financial information. These are all needed to conduct a financial feasibility study [72].

1. Fixed Capital Investment
2. Working Capital
3. Total Capital Investment
4. Total manufacturing expenses
5. Packaging and in plant expenses
6. Total operating expenses
7. Marketing Data
8. Cash Flow Analysis
9. Project Profitability
10. Sensitivity Analysis
11. Uncertainty Analysis

The methodology discussed in this chapter is accepted as the norm in estimating the capital cost of a chemical plant.

2.3.2 Methods of Estimating Capital investment cost

In the processing industries, there are five capital cost estimates that are generally encountered. They are listed below: [73]

1. Detailed estimate
2. Definitive estimate
3. Preliminary estimate
4. Study estimate
5. Order of magnitude estimate

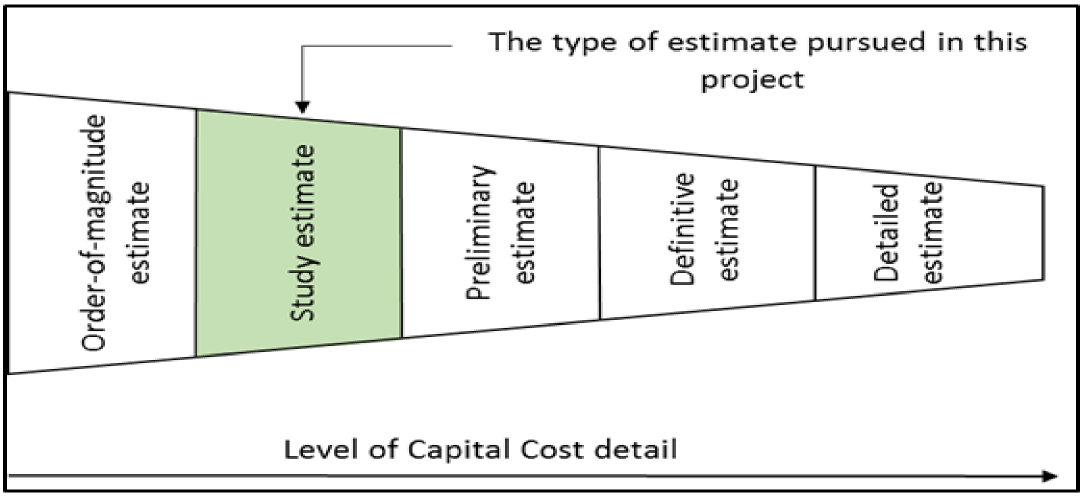


Figure 2-18: The detail of the Capital Cost estimate, compared to other estimates [73].

The AACE Recommend practice No 17R-97 are approximately the same as those listed above [73]. This information gives a guideline to the range of each estimate. Each cost estimation is done relative to Class 1 which is the most accurate estimate. A Class 1 estimate falls in the range of +6% to -4% accurate. Hence the true price would be 6% higher or 4% lower than the price estimation. A Class 3, for example, has an accuracy range of 2 to 6 relative to Class 1. Multiplying that with the range of Class 1 means the lowest expected cost range will be between -8% and +12% and the highest expected cost range will be between -24% and +36 % of the actual capital cost.

To achieve a cost estimation of a processing plant, the costs of the major plant equipment must be known. An up to date quote from a seller of the required equipment is the most accurate estimate of the purchase cost of this equipment. It may happen that this is hard to obtain. The next best substitute is to use data of similar and previously purchased equipment. However, time may have elapsed since this equipment was purchased and the capacity may differ to that required for the estimate. This can be adjusted to account for the time elapsed and the difference in capacity.

2.3.2.1 The capacity adjustment

If there is a difference in the capacity of an obtained quote and the planned output capacity, the equipment cost can be adjusted using Equation 2.1 [72].

$$\frac{C_a}{C_b} = \left(\frac{A_a}{A_b}\right)^n \tag{2.1}$$

Where:

A = Equipment cost attribute

C = Purchased cost

n = Cost exponent

a denotes the equipment with the required attribute *b* denotes the equipment with the base attribute

The plant output capacity is usually the attribute used as input in the calculation. The value of *n* differs for different types of equipment. 0.6 Known as the six-tenths-rule is used in general as the value of n as 0.6 is the average value of all equipment [71].

Table 2-3: What each class of estimate entails [73].

Class of Estimate	Level of Project Completion [%]	Typical Purpose of Estimate	Methodology (Estimating Method)	Expected Accuracy Range [+/- Range Relative to Best Index of 1]	Preparation Effort [Relative to Lowest Cost Index of 1]
Class 5	0 to 2	Screening or Feasibility	Stochastic or Judgement	4 to 20	1
Class 4	1 to15	Concept Study or Feasibility	Primarily Stochastic	3 to 12	2 to 4
Class 3	10 to 40	Budget Authorisation or Control	Mixed but Primarily Stochastic	2 to 6	3 to 10
Class 2	30 to 70	Control or Bid/Tender	Primarily Deterministic	1 to 3	5 to 20
Class 1	50 to 100	Check Estimate or Bid/Tender	Deterministic or Judgement	1	10 to 100

2.3.2.2 The time adjustment

If the only cost data that could be found is a few years old, then another adjustment must be made to account for changing economic conditions better known as inflation. To convert the old cost to what it should be today equation 2.2 in conjunction with cost indexes can be used [72].

$$C_2 = C_1\left(\frac{I_2}{I_1}\right) \tag{2.2}$$

Where:

C = Purchased Cost

I = Cost index

1 refers to the base time when the cost is known

2 refers to the time when the cost is desired

The cost indexes that is most commonly accepted in the industry are the Marshall and Swift Equipment Cost Index and the Chemical Engineering Plant Cost Index (CEPCI). To account for the effect of time the following is done. The index at the desired time step is divided by the index at the time of available data and then multiplied by the available cost data. This is a speculative figure but it is required.

2.3.2.3 Accounting for inflation.

The previous section dealt with adjusting for inflation for past data, this section deals with adjusting for inflation if the project is to be done in the future. This is to account for inflation from the time of estimation to the planned installation time. Equation 2.3 illustrates an example of accounting for inflation three years in advance [71].

$$C_i = (1 + f_1)(1 + f_2)(1 + f_3)C_p \tag{2.3}$$

Where:

C_i = Inflated cost

f_1 = Inflation rate in the first year

f_2 = Inflation rate in the second year

f_3 = Inflation rate in the Third year

C_p = Cost in the base year

2.3.2.4 Estimating the total plant cost

The previous sections focused on adjusting the cost data to the desired time and capacity. There are however additional costs that should be added to the estimate the cost of the entire plant. According to Turton [73] the purchased cost of the equipment is less than a third of the total capital cost of the plant. A widely used method is the Lang factor method [74]. The total cost is determined by multiplying all the major equipment purchased cost by a certain factor. The major items of a plant are those depicted in the process flow diagram. Seider [74] multiplies Flang in equation 2.4 with 1.05 to cover delivery cost. To the plant site. The factor also depends on whether the plant processes fluids or solids [74].

$$C_{TM} = F_{Lang} \sum_{i=1}^{n} Cp,i \tag{2.4}$$

Where:

C_{TM} = Capital Cost (total Module) of plant

$C_{p,i}$ = Purchased Cost for Major Equipment Units

n = Total number of Individual Units

F_{Lang} = The Lang Factor

Choy [64] also uses the Lang factor method to estimate and to calculate the remaining capital investment after the equipment has been purchased. It is used regularly to an accuracy of 20-30%. The remaining capital investment is divided into direct cost and indirect cost and this method typically accounts for the following.

i The direct costs

Several other factors besides the equipment cost should be considered in the appropriation of the capital investment. The factors associated with direct costs include the following and the multiplication factors are depicted in Table 2-4 [75]:

1. Purchased-equipment installation and erection
2. Insulation, painting and piping
3. Power and lighting and other electrical equipment
4. Controls and other instrumentation
5. Structures and process buildings
6. Site development (yard improvements)
7. The service facilities of a plant
8. Land

Table 2-4: The Multiplication factors for the direct costs for use in the Lang factor method [75].

Direct costs			
Item	**Solid-processing plant**	**Solid-Fluid processing plant**	**Fluid-processing plant**
Purchased equipment-delivered (fabricated equipment + process machinery)	100	100	100
Purchased-equipment installation	45	39	47
Controls and instrumentation	9	13	18
Piping	16	31	66
Electrical	10	10	11
Buildings	25	29	18
Yard improvements	13	10	10
Service facilities	40	55	70
Land (if it must be purchased)	6	6	6
Total direct plant cost	264	293	346

ii The indirect costs

The indirect costs are incurred during the construction of the plant. The multiplication factors of these cost are displayed in Table 2-5. It includes the following costs [64]:

1. Engineering and supervision cost
2. The expense of the construction
3. The fee of the contractor
4. Contingency cost

Several more thorough methods exist but the Lang Factor method is suitable for a study estimate.

Table 2-5: The Multiplication factors for the indirect costs for use in the Lang factor method [75].

Indirect costs			
Item	**Solid-processing plant**	**Solid-Fluid processing plant**	**Fluid-processing plant**
Engineering and supervision	**33**	**32**	**33**
Construction expenses	**39**	**34**	**41**
Contractors fee	**17**	**18**	**21**
Contingency	**34**	**36**	**42**
Fixed capital investment	**387**	**413**	**483**

2.3.3 The manufacturing Cost Estimation models

Various elements influence the cost of running a manufacturing operation. These elements are divided into three main categories.

- Direct manufacturing costs
- Fixed manufacturing costs
- General Costs

The following equation is used to account for these costs [72] :

$$COM = DMC + FMC + GE \qquad (2.5)$$

Where:

COM = Cost of Manufacturing

DMC = Direct manufacturing Costs

FMC = Fixed Manufacturing cost

GE = General Expenses

The following values are needed to use the equation 2.5:

- Fixed Capital Investment (*FCI*)
- Cost of Operating Labour (C_{OL})
- Cost of Utilities (C_{UT})
- Cost Waste Treatment (C_{WT})
- Cost of Raw Materials (C_{RM})

All other manufacturing costs can be estimated when these values are known. Turton [73] provides multiplication factors to calculate the unknown costs.

2.3.3.1 Direct Manufacturing Costs

These costs are directly related to the production rate. Typical direct costs are raw materials, utilities (water, electricity) and other miscellaneous operating costs. Table 2-6 illustrates the equations that may be used to approximate each individual item. For each item, a typical range is depicted. If no other information is available the midpoint between the ranges is used to approximate the costs. It must be mentioned that the best information available should always be used. By using the midpoint value, equation 2.6 [73], is used to estimate the Direct Manufacturing cost.

$$DMC = C_{RM} + C_{WT} + C_{UT} + 1.33C_{OL} + 0.03COM + 0.069FCI \tag{2.6}$$

Table 2-6: Direct Manufacturing Cost with the multiplication factors [73].

Direct Manufacturing Cost	Typical Range of Multiplication Factors	Values used
Raw materials	C_{RM}	C_{RM}
Waste treatment	C_{WT}	C_{WT}
Utilities	C_{UT}	C_{UT}
Operating labour	C_{OL}	C_{OL}
Direct supervisory and clerical labour	$(0.1 - 0.25)C_{OL}$	$0.18C_{OL}$
Maintenance and repairs	$(0.02 - 0.1)FCI$	$0.06FCI$
Operating supplies	$(0.1 - 0.2)(0.02 - 0.1)FCI$	$0.009FCI$
Laboratory charges	$(0.1 - 0.2)C_{OL}$	$0.15C_{OL}$
Patients and royalties	$(0 - 0.06)COM$	$0.03COM$

2.3.3.2 Fixed Manufacturing Costs

These costs are independent of fluctuations in the production rate. It includes the following: Insurance, property taxes and others which are charged even when the plant is not in operation. For each item, a typical range is depicted in Table 2-7. By using the midpoint value of these ranges, equation 2.7 [73] is used to estimate the Fixed Manufacturing cost.

Table 2-7: Fixed Manufacturing Cost with the multiplication factors [73].

Fixed Manufacturing Costs	Typical Range of Multiplication Factors	Values Used
Depreciation	**0.1*FCI***	**0.1*FCI***
Local Taxes and Insurance	**(0.014 - 0.05)*FCI***	**0.032*FCI***
Plant overhead Costs	**(0.5 – 0.7)(C_{OL} + (0.1 - 0.25)C_{OL} + (0.02 - 0.1)*FCI*)**	**0.708C_{OL} + 0.036*FCI***

$$FMAC = 0.708C_{OL} + 0.068FCI + depreciation \tag{2.7}$$

2.3.3.3 General Costs

It is an overhead burden but it is required to carry out the business functions. It includes: Management, financing, sales, and research functions. For each item a typical range is depicted in Table 2-8. By using the midpoint values of these ranges equation 2.8 [73], is used to estimate the General Expenses.

Table 2-8: General Expenses with the multiplication factors [73].

General Manufacturing Expenses	Typical Range of Multiplication Factors	Values Used
Administration Costs	**0.15(C_{OL} + (0.1 - 0.25)C_{OL} + (0.02 - 0.1)*FCI*)**	**0.177C_{OL} + 0.036 *FCI***
Distribution and selling costs	**(0.02 – 0.2)*COM***	**0.11*COM***
Research and development	**0.05*COM***	**0.05*COM***

$$GE = 0.177C_{OL} + \ 0.00FCI + 0.16COM \tag{2.8}$$

2.3.4 Economic Analysis

The goal of a manufacturing company is to make money. This is accomplished by adding value to low-value raw materials and transform them into products with a high market value.

2.3.4.1 Depreciation

A manufacturing plant has a finite life, over time the value of the plant will decrease. Therefore depreciation has to be taken into account. The factors playing a role in this, will be discussed.

Fixed Capital Investment, *FCI_L*: This is the fixed capital investment to build the plant minus the cost of the land.

Salvage Value, *S*: This is the fixed capital investment minus the value of the land at the end of the plant life. It is usually a very small fraction of the initial capital investment, sometimes it is even assumed to be zero.

Life of Equipment, *n*: This is not the actual working life of the equipment but the time allowed for depreciation by the tax authority.

The difference between the fixed capital investment and the salvage value is the total amount of depreciation allowed [72].

$$D = FCI_L - S \tag{2.9}$$

Where D = Total capital for depreciation.

Yearly depreciation, d_k: The depreciation amount varies from year to year, d_k is the amount allowed in the kth year.

Book value: The book value is the amount of capital that is depreciable, but that has not yet been depreciated [72].

$$BV_k = FCI_L - \sum_{1}^{k} d_j \tag{2.10}$$

Three deprecation methods are commonly used to determine depreciation allowed each year.

Straight Line Depreciation Method, SL: An equal amount is charged each year over the allowed deprecation period [72].

$$d_k^{SL} = \frac{[FCI_L - S]}{n} \tag{2.11}$$

Sum of years Digits Depreciation method, SOYD: The formula is given below [72].

$$d_k^{soyd} = \frac{[n+1-k][FCI_L - S]}{\frac{n}{2}[n+1]} \tag{2.12}$$

Double Declining Balance Deprecation Method, DDB: A constant fraction of the book value is used [72]: BV_{k-1}

$$d_k^{DDB} = \frac{2}{n}\left[FCI_L - \sum_{j=0}^{j=k-1} d_j\right] \tag{2.13}$$

It must be mentioned that the IRS only approves the straight-line and double declining methods. The next section will look at the time value of money

2.3.4.2 Time Value of Money

In business, money is borrowed or loaned. When the money is returned it is done so with interest, to compensate the lender for the risk of lending money and the fact that the lender could have invested the money somewhere else and made a profit. From the borrowers standpoint interest can be seen as the cost of borrowing money. The interest depends on scarcity of money, size of the loan, length of the loan, the risk that the lender feels he/she is taking and the current economic conditions.

The amount of the loan is termed the principal or present worth (P). (F) The future amount of the money is always greater than the principle (P). The relation that P and F has depends on the type of interest used. There are two types of interest when calculating the future amount, namely simple and compound interest. Equation 2.14 depicts the calculation of simple interest [72]. The simple interest concept is rarely used in business. The interest is only charged on the initial loan and not on the balance due.

$$F_n = P(1 + i_s n) \tag{2.14}$$

Where

P = Principle

F = Future value

i_s = Simple Interest Rate

n = Number of Years

When the interest earned is not set aside but added to the principle in that time period it is called compound interest. In the next time period, the interest is calculated upon the principle plus the interest from the preceding time period. Equation 2.15 depicts the formula to calculate the future value in the case of compound interest [72].

$$F_n = P(1 + i)^n \tag{2.15}$$

We can also reverse this to ask what should I invest now (*P*), to earn a certain amount F_n in *n* years time [72].

$$P = \frac{F_n}{(1 + i)^n} \tag{2.16}$$

The effective interest rate can be calculated when the interest rate is not given as compounded per year. It converts interest rate given as monthly, quarterly, or bi-annual to an effective annual interest rate [72].

$$i_{eff} = \left(1 + \frac{i_{nom}}{m}\right)^m - 1 \tag{2.17}$$

i_{eff} = Effective annual Interest Rate

i_{nom} = Given Nominal interest Rate

m = Number of Compounding Periods per year

In order to undertake the initial capital investment cost a loan needs to be made and repaid in monthly segments. Equation 2.18 is used to calculate the monthly instalments amount [72].

$$A = P\frac{r(1+r)^n}{(1+r)^n - 1} \tag{2.18}$$

Where:

A = Payment Amount per Period

P = Initial Loan Amount

r = Interest rate per Period

n = Number of Payments or Periods

2.3.4.3 Taxation

Taxation has a direct influence on the profits gained from building and operating a plant. Income and deprecation influence the amount of income tax that should be paid. Turton [73] offers formulas for calculating the income tax, after-tax net profit and after-tax cash flow in equations 2.19-2.21

$$Income\ Tax = (R - COM_d - d)(t) \tag{2.19}$$

$$Net\ Profit = (R - COM_d - d)(1 - t) \tag{2.20}$$

$$After - Tax\ Cash\ Flow = (R - COM_d - d)(1 - t) + d \tag{2.21}$$

Where

COM_d = Cost of Manufacture excluding depreciation

d = Depreciation

t = Tax Rate

R = Revenue from Sales

2.3.4.4 Cumulative Cash Position Plot

All expenditures as well as the revenue from sales are plotted as a function of time. It gives a running total cash flow up to a point in time. Discounting factors are added to account for the time value of money. The discounted NPV can be calculated by discounting projected future profits. This can be used to compare future projects.

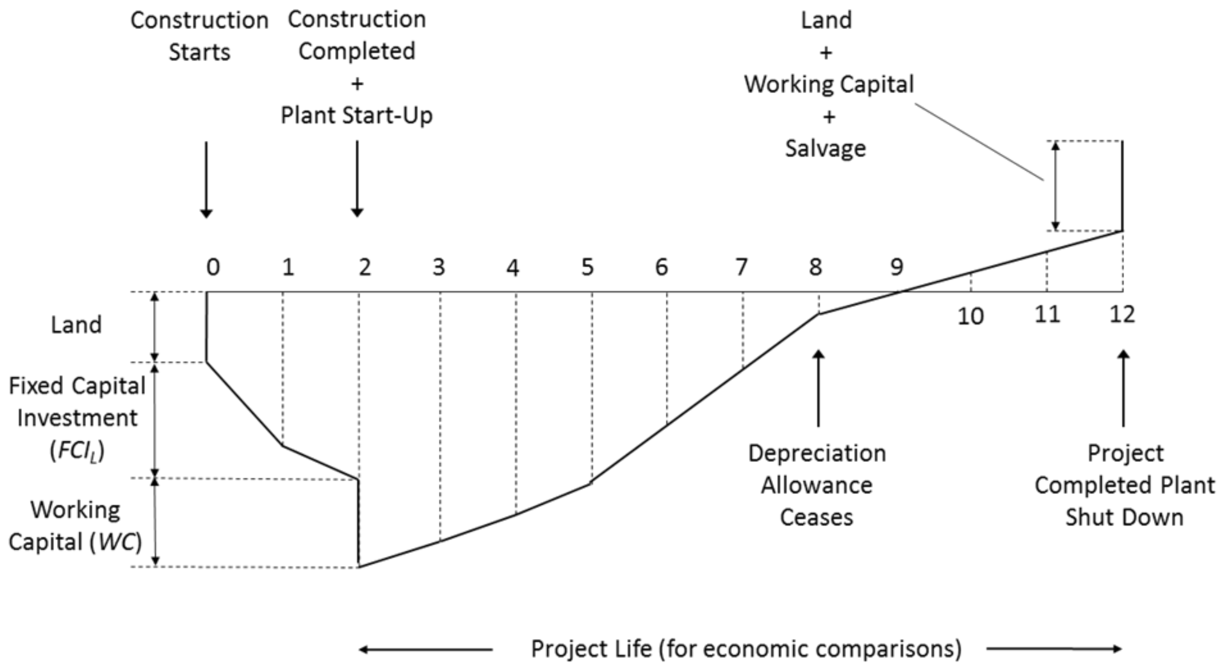


Figure 2-19: An Example of a Cumulative Cash Flow Diagram for evaluating a new project [73].

As can be seen in Figure 2-19 the construction of a plant can take anywhere between 6 months and 3 years, but a value of 2 years was assumed in the figure, from the project initiation to the start-up. Over the 2 year construction phase there is a major capital outlay, this is the fixed capital expenditure. At the end of the 2nd year, construction is completed and the plant is started. Working capital is required to support the first few months of operations. This is a once off expense and will be recovered at the end of the project.

The process will now begin to produce products for sale, hence the annual cash flows will become positive. This is shown in the positive slope, as the slope will be steeper in the earlier years due to the depreciation allowance. To evaluate the profitability of the project the life span for the project must be assumed. The profitability of a project is directly related to the life of the project. 10, 12 or 15 years is a good assumption. At the end of the life period, we assume the plant is closed and sold for scrap, however, in reality, this will most likely not be the case. In Figure 2-19 the cumulative CFD is positive. From this one might immediately think that the project is profitable, but to conclude on this, it must be known whether the value earned was smaller or greater than the investment in the beginning of the project. Therefore, the time value of money must be considered when evaluating profitability.

2.3.5 Profitability analysis

A profitability analysis is built on three pillars: Time, cash and interest rate. Two techniques exist discounted and non-discounted. The former is still used in smaller projects, but it is not recommended for new larger projects as it does not take the time value of money into account.
For the purpose of this study, non-discounted profitability criteria will not be considered.
With the discounted profitability criteria each of the yearly cash flows are discounted back to time zero. The subsequent discounted cumulative cash flow diagram is used to evaluate profitability.
Time Criterion DPBP is the discounted payback period, it is better defined as the time required to recover FCI_L, with all the cash flows discounted back to time zero. The project with the shortest discounted payback period is the most desirable. Green and Perry names it the Pay-out Period Plus interest, equation 2.22 depicts the calculation [72].

$$POP + I = \frac{Depreciable\ Fixed\ Capital\ Investment}{After - Tax\ Cash\ Flow} \tag{2.22}$$

Cash Criterion

The discounted cumulative cash position is used in the cash criteria. It's also known as the Net Present Value (NPV) or the Net Present Worth (NPW). It is the cumulative discounted cash position at the close of the project. The calculation is depicted in equation 2.23 [72].

$$NPV = PV\ of\ all\ Cash\ Inflows - PV\ of\ all\ Investment\ Items \tag{2.23}$$

A Present Value Ratio, equation 2.24 is a better criterion when comparing projects with different investment levels [72]. The NPV calculation is subject to the level of fixed capital investment. If the value is greater than one the project is profitable, if the value is less than one, the project is not profitable.

$$PVR = \frac{PV\ of\ All\ positive\ Cash\ Flows}{PV\ of\ All\ Negative\ Cash\ Flows} \tag{2.24}$$

Interest Rate Criterion

Interest Rate Criterion uses a discounted cash flow rate of return (DCFROR) to evaluate profitability. DCFROR entails determining an interest rate for which the net present value equals zero. Therefore, it is the highest after-tax interest rate at which the project can break even.

Return on investment

Choy [64] does a basic return on investment calculation before conducting the detailed economic evaluation. Note that revenue is generated by selling the product.

$$ROI = \frac{annual\ profit}{total\ capital\ investment}(100\%) \quad (2.25)$$

$$ROI = \frac{annual\ sales\ revenue - annual\ production\ cost}{total\ capital\ investment}(100\%) \quad (2.26)$$

For further evaluation, the net present value (NPV) calculation and the IRR calculation can be used. A Risk analysis is also used to explore how changes in the forecast data effect economic feasibility.

2.3.6 Risk analysis to manage uncertainty

Up until now, a deterministic approach has been taken, this means that it has been assumed that all the values are known with certainty. Many of the estimates can be subject to error and the question is not if they change, but rather how much they change. The most important variable is the sales volume, the product price and the raw material is a close second. The initial estimates may vary significantly over a 10 year period, for example, the profitability would be effected greatly if one were only to sell 50% of the original estimate. There are methods to quantify risk and to investigate uncertainty. Scenario and sensitivity analysis as well as a Monte Carlo simulation to explore and account for uncertainty. Quantifying risk does not eliminate uncertainty, but by doing so a better idea can be developed for how a project's profitability might vary. The ultimate decision to invest in a plant always involves some risk.

Table 2-9: Factors with variation ranges for sensitivity analysis [72].

Factor in Profitability Analysis	Probable Variation over 10 Year Period [%]
Cost of Fixed Capital Investment	**-10 to +25**
Construction Time	**-5 to +50**
Start-up Costs and Time	**-10 to +100**
Sales Volume	**-50 to +150**
Price of Products	**-50 to +20**
Plant Replacement and Maintenance Costs	**-10 to +100**
Income Tax Rate	**-5 to +15**
Inflation Rate	**-10 to +100**
Interest Rate	**-50 to +50**
Working Capital	**-20 to +50**
Raw Material Availability and Price	**-25 to +50**
Salvage Value	**-100 to +10**
Profit	**-100 to +10**

2.3.6.1 Scenario Analysis

Scenario analysis is a method to compute uncertainty. The best and the worst-case scenarios are measured and are then compared with the base case (the original estimate.) [73] uses an example where the product price, capital investment and the cost of manufacturing are varied between the worst case, base case and best case. This means that there are 27^3 combinations. All the cash flows are discounted to the start of the project to determine the NPV's. It is not very likely that one of these scenarios will occur. A better measure of the expected probability would be the weighted average of the 27 possible combinations. Weighing the results on the basis of the likelihood of occurrence would be a better way of estimating risk. Yet another factor to consider is the sensitivity of the profitability to changes in important parameters.

2.3.6.2 Sensitivity Analysis

The risk associated with the variability of a parameter is dependent on the effect that a change in parameter has on profitability. The measure of profitability can be any of the following NPV, DCFROR or DPEP, for the sake of the discussion NPV is used. If the NPV is affected by parameters (x_1, x_2, x_3 , x_n) then the effect that the parameter x_1 would have on the NPV is depicted in equation 2.27 [72].

$$S_1 = \left[\frac{\delta(NPV)}{\delta x_1}\right]_{x_2,x_3,\dots,x_n} \tag{2.27}$$

The partial derivative is taken with regards to x_1 and all the other parameters are kept constant. S_1 is called the sensitivity coefficient. In common it is too complicated to obtain the sensitivity via analytical differentiation. Therefore, it is done by changing the parameter by a small amount and observing the change in the NPV. Equation 2.28 illustrates this [72].

$$S_1 = \left[\frac{\Delta(NPV)}{\Delta x_1}\right]_{x_2,x_3,\dots,x_n} \tag{2.28}$$

When the sensitivity coefficient is calculated Equation 2.29 can be used to predict the change in the NPV for a set of changes in the parameters [72].

$$\Delta NPV = S_1\Delta_{x_1} + S_1\Delta_{x_2} + \cdots + S_n\Delta_{x_n} \tag{2.29}$$

2.3.6.3 Monte Carlo Simulation (M-C)

Monte Carlo Simulation entails the assigning of probability distributions to parameters and repeatedly choosing variables from these distributions and then using these values to calculate a function dependant on these variables. The eight steps discussed below is just a case of the M-C method.

1. Identify all the parameters for which uncertainty must be quantified.
2. Assigned probability distributions to the parameters in step 1.
3. Assign a random number for each parameter in step 1.
4. Assign a value to the parameter by using the number from step tree and the probability distribution for that number from step 2.
5. The profitability of the project is calculated by using a NPV or any other criteria.
6. Repeat steps 3, 4 and 5 several times (1000 times or more.)
7. Create a cumulative probability curve or histogram for the results of step 6
8. The profitability of the project is determined by analysing the results of step 7

The Monte Carlo simulation will be conducted with the help of the @Risk Software. It mathematically computes the different possible future scenarios. It then tells the risks associated with each one. It accompanies the decision process to decide which risk to take and which risk to avoid. [76]

@Risk can be used to fit a range of distributions with a data set. Amongst the various types of distributions that exist, uniform and triangular are the simplest. In a uniform distribution, a parameter is allowed to have a value between a and b, with equal probability. A triangular distribution has a minimum (a), a most likely value (b) and a maximum (c). In this distribution, the chance is good that a value close to the most likely value will be chosen. The triangular probability functions are given by equations 2.30-2.31 [72].

$$p(x) = \frac{2(x-a)}{(c-a)(c-b)} \; for \; x \leq b \tag{2.30}$$

$$p(x) = \frac{2(c-x)}{(c-a)(c-b)} \; for \; x > b \tag{2.31}$$

Normal, lognormal and trapezoidal can easily be used. To conclude the M-C simulation helps the user to compute the probability of a project being profitable quantitatively. This, in turn, is used to make the most informed decision while considering the risks and its likelihood of occurrence.

Chapter 3 Research Methodology.

3.1 Introduction

A short summary of the research methodology was discussed in section 1.3. Figure 3-1 illustrates the process flow of the method used to attempt this study. The diagram depicts the flow of work and tasks, and how they related to each research objective.

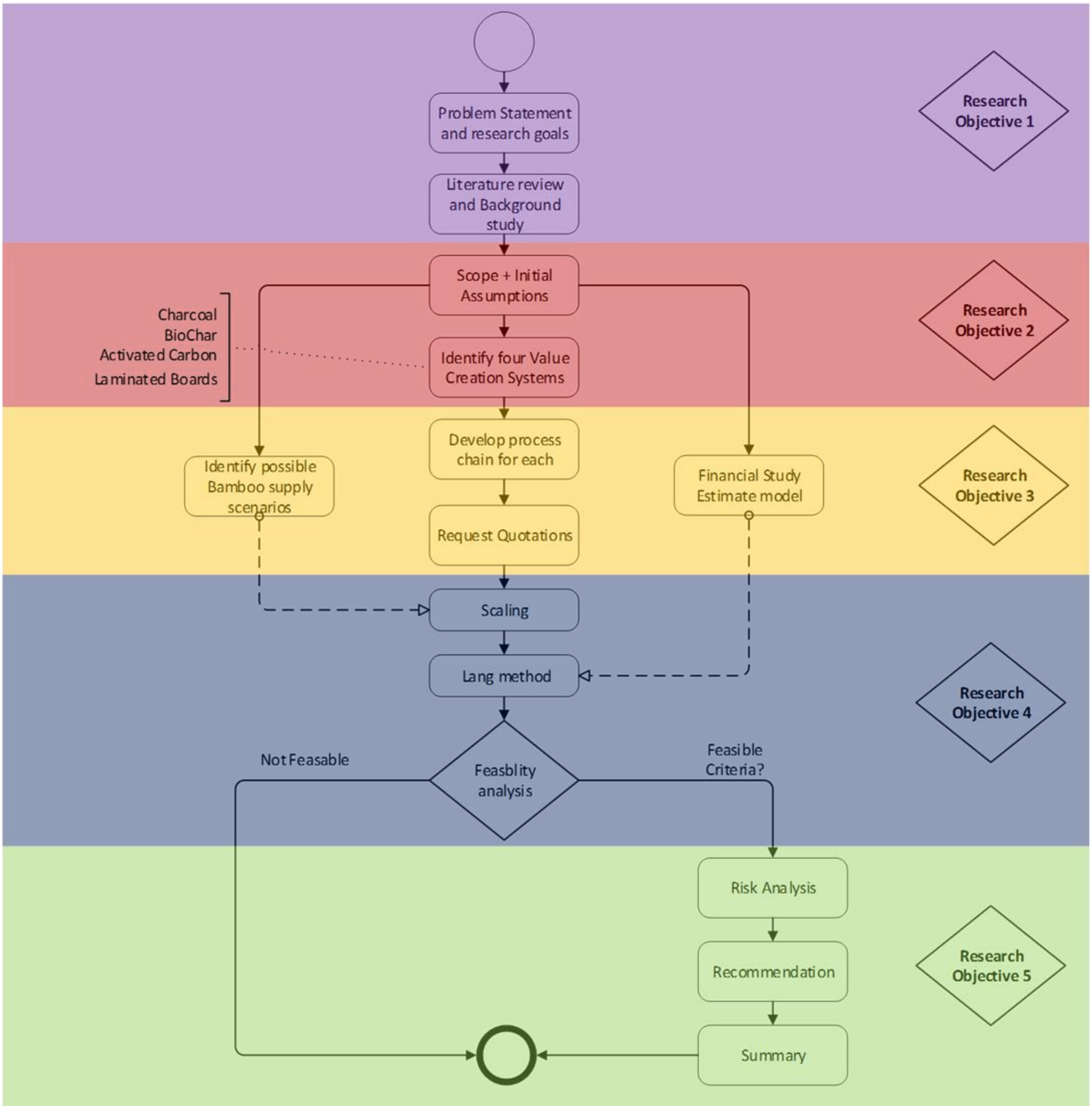


Figure 3-1: This diagram depicts the scope of the study and it correlates with the five research objectives of the project.

In this section, however, the method used to approach the project is better explained. The journey to solving the problem is explained in this chapter. The approach taken was to be as realistic as possible given the constraint of time to gather all the information. First the possible yield amounts for the project had to be determined. It was decided to investigate seven different yield scenarios. To obtain all the financial data proved to be quite a challenge. Companies have no real motivation to spend time on preparing detailed quotations if they do not benefit from it. Hence there was no real motivation for them to supply quotations of large machinery units if it was not strictly for business. Therefore the strategy used to approach these companies had to be well structured and professional. The financial data was obtained between the period of 2016 and 2017.

Seven different input yields for each of the four value creating system were used to construct the model. This adds up to a total of 28 scenarios for the project. Each scenario is investigated over a period of ten years. The cumulated discounted cash flows at the end of the ten year period will be considered to determine whether the project is feasible or not. If the cumulated discounted cash flows at end of the period are positive the project is considered to be feasible. If the cumulated discounted cash flows at end of the period are negative the project is considered to be unfeasible and the analysis on the particular scenario will be ceased.

The analysis will continue on all the cases where the cumulated discounted cash flows at end of the period are positive thus on all the scenarios that were considered feasible.

For each of these scenarios the @Risk software will be used to vary the base inputs over an interval. The results obtained in the risk analysis are used in conjunction with an index developed for this study to determine which value-creating system creates the most value. The scenarios are also considered over the yield spectrum to see which scenario makes the most sense at which yield.

3.2 The scenarios

In the experiment section seven different yields are used as input data. The yield amounts selected, accounts for several scenarios which includes three different projected yields per hectare as well as different development stages. As mentioned above the scenarios will also be considered over the yield spectrum to see which scenario makes the most sense at which yield.

For example the study can conclude that if the total bamboo yield of the development is between 500 and 1000 ton a Biochar facility will have the least amount of risk and will be the most profitable. In the range of 1000 to 5000 ton Charcoal could prove to be the best option, whilst Activated Carbon could be the winner from 10 000 ton to 50 000 ton and so forth.

The seven yields amounts are 500, 1000, 2500, 5000, 10000, 50000 and 100 000 ton

These amounts are generated by the three scenarios depicted in Table 3-1, Table 3-2 and Table 3-3 ,yet the possible yields include several other scenarios.

Table 3-1: The possible yield scenarios with 50 hectares planted.

A first stage development of 50 hectares	
Yield per ha per annum	Yield for the development (Ton)
10	500
50	2500
100	5000

Table 3-2: The possible yield scenarios with 100 hectares planted.

A first stage development of 100 hectares	
Yield per ha per annum	Yield for the development (Ton)
10	1000
50	5000
100	10 000

Table 3-3: The possible yield scenarios with 1000 hectares planted.

The full development of 1000 hectares	
Yield per ha per annum	Yield for the development (Ton)
10	10 000
50	50 000
100	100 000

3.3 The universal input values and other value differentiations

3.3.1 The universal input values

The universal input values refer to the values that were the same for all the scenarios. This includes different rates, water and electricity as well as the labour cost. Some of these values will be varied in the simulation that will be carried out on the scenarios that are considered feasible.

The prime lending rate was 10.5% at the time of study (June 2017) [77]. This is the average rate of interest charged on loans by major commercial banks to companies and private individuals. The interest rate or discount rate was taken at 7% [77].

Corporate income tax is calculated at a rate of 28% as depicted by SARS [78]. The Rand-Dollar exchange rate was taken as an average between the period of 31/07/2016 to 11/06/2017. The rate is R 13.6022 to one Dollar.[79]. The electricity rate was determined using the Eskom tariff book for the rates of 2017/2018. The Business rate for non- local authorities was used in the study. The Business rate includes the Energy charge 95.30 c/kWh, Ancillary charge 0.37 c/kWh and the Network demand charge 13.46 c/kWh, which sums to 109.13 c/kWh without VAT and 124.4 c/kWh VAT included. Additional charges are the Network capacity charge 64.11(R/POD/day) VAT included and the Service and administration charge 19.03 (R/POD/day) VAT included [80]. The water tariff was taken as the industrial tariff for the Matlosana municipality where the production facilities will be stationed. The industrial tariff is R21.64 per kiloliter including VAT. The average amount of workdays per annum are 249 days [81].

The labour cost is a factor that is varied in the simulation. The Middle value is used as the base value in all of the scenarios, while it is varied over an interval in the simulation. The different values were obtained from different sources and are used to induce variation in the simulation. The middle or most likely value of R 46.48 per hour is used. This is considered as the base salary of a skilled Plant and systems operator [82].

3.3.2 Increases

The price of electricity will rise with 8% from 2013-2018 [83]. The increase for water ranges between 8% [84] and 13% [85]. The wage increase in South Africa in 2015 were 7.7% and in 2016 it was predicted to be anything between 7.4% to 7.9% [86]. These costs are all included in the manufacturing costs or also known as OPEX (operating expenses). The OPEX will rise every year with a set rate, but the product price will also increase with a specific rate every year. In Accordance with the study leader it was decided that the product price will increase with such a rate, that the profit margin or net annual cash flow as it is referred to in the model will stay constant. Therefore this means that if the OPEX for any given year is subtracted from the total revenue generated by the product for that year, it will be the same amount as the previous year.

3.3.3 Yield

Yield data of commercially planted bamboo in South Africa is limited, and therefore it required the researcher to look at data that was available for the specie, Bambusa balcooa. A very conservative source reported that Bambusa Balcooa yields 3 ton per ha [87]. This is contradicted by most other sources. A better estimate will be 50 ton per ha. This is confirmed by Graham Dunbar [40] the director of BrightFields Natural Trading Co situated in Cape Town. Pandey et al. [88] does not specify a specie but states that a managed bamboo stand must deliver at least 40 tonnes or more per ha annually. Another research study [89] reported a Bambusa Balcooa plantation yielding 50 ton per ha per year. Mr Peter Pearce of Bam d'Afrique [90] a man that has dedicated the latter part of his life to establish a bamboo industry in South Africa is of the opinion that 100 ton per ha is a good estimate. Growmore Biotech Ltd underlines Mr Peter Pierce's estimation as depicted in Table 3-4. Their statistics is on Beema bamboo, which is a high yielding superior biomass clone developed from Bambusa Balcooa by Dr N. Barathi [91].

Table 3-4: Possible yields with Beema Bamboo a high yielding clone of bamusa balcooa [91].

Years	Yield [Tons per Ha per year]
3	**62.5 to 75**
4	**100 to 125**
5	**125**

It was decided that for the project 3 different yields per ha will be considered. A yield of 10 ton per ha per year, 50 ton per ha per year and 100 ton per ha per year. These assumed yields all fall within the variation depicted by the sources.

The project aims to establish a 1000 ha bamboo plantation. In full production the three possible yield amounts selected will be 10 000 ton, 50 000 ton, 100 000 ton per hectare per annum.

3.3.4 Moisture content

The moisture content influences the weight of the bamboo, hence it is important to consider. In the harvesting season the bamboo has a certain moisture content. The bamboo can lose significant weight from harvesting until it is used for manufacturing through losing moisture. This was realised in an experiment done over a period of 50 days by the researcher. Ten pieces of bamboo was weighed for 50 consecutive days. The bamboo were exposed to normal indoor conditions, as it would be after harvesting. During this period a significant decrease in weight was witnessed. The graph displaying the weight loss can be seen in Appendix A. As the bamboo dries, it shrinks Burger et al. [23], suggests that it shrinks 10-16% in diameter and 15-17% in wall-thickness. It is important to consider this when calculating the weight of the biomass that will be produced. Equation 3.1 can be used to calculate the moisture content. [92]

$$MC\%\ (Green\ basis) = \left(\frac{weight\ of\ water}{weight\ of\ water + dry\ weight\ of\ wood}\right) x\ 100 \qquad (3.1)$$

Sources differ on the moisture content that is present in the bamboo at harvest. Fu [93] states that the moisture content of moso bamboo at cutting age is approximately 80%. They also state that it varies in different culms and with different species. Fu [93] estimates the equilibrium at around 15.7%. But it is quite dependant on the temperature and the humidity fluctuations. However Liese [25] states that although younger culms can have a moisture content of 60 – 87% it becomes more or less constant at 22% - 40%. The middle of the interval which is 31% moisture content, will be used for the calculations in this project.

3.3.5 Culm weight and amount

It is important to consider the culm weight when looking at the production of bamboo lumber. Most of the throughput data are specified in culms per hour. To calculate the available culms, a good estimation on the average weight of a culm is needed. The assumed yields can then be divided by the average culm weight to determine the available amount of culms per ha. Mr Peter Pierce [90] estimated the average weight at 70 kg per culm. In a study done on bambusa balcooa, the total culm weight was reported as 73.698 kg [89], with the economical part as 61.86 kg [87]. This data was retrieved from a plot that yielded 1500- 2000 culms per ha after the 7th year of the plantation. A study done by Choudhury [94] reported that the fresh weight of the culm were 35.16 kg at the age of four years, which is the year in which harvesting takes place. It is safe to assume that the weight of the culm will be between 35 and 70 kg. For the purpose of this study the middle of the interval which is 52.5 kg will be used in calculations. The upper limit of the assumed yield of 100 ton per ha divided by 52.5 kg gives 1904,762 culms Which corresponds with Salam [87] who reports 1500 to 2000 culm per ha.

3.3.6 Sustainable development index

The need arose to evaluate the scenarios in the context of sustainable development. In the literature study the definition of sustainable development were supported by three main pillars, namely, economic, environment and society. It was decided to attempt an evaluation of the project at the hand of each of these three pillars. Before exploring this possibility, a sustainability index must first be defined and a quick glimpse will be taken at current Indexes.

The Human Sustainable Development Index (HSDI) was proposed a while back to complement the iconic United Nations Human Development Index (HDI) by adding an environmental dimension. It was reasoned that the HDI places developed and oil rich nations high on the charts without considering what their development is costing the planet and how it imperils future human development. The HDI covers two of the three dimensions of sustainability, the economic and the social. The social component includes life expectancy and education and the economic dimension includes the GDP per capita [95]. An HDI value of 1 indicates that a country has attained the maximum value for each sub-index. Each of these subcomponent is represented by a sub-index which is calculated as depicted in Equation 3.2:

$$I_{dim} = \frac{x - min}{max - min} \tag{3.2}$$

X is the observed value for a given country, this maximum value is the highest observed value in a certain period and the minimum is the minimum value observed in a certain period or certain set minimums, such as 20 years life expectancy for example. The HSDI adds an environmental dimension, by calculating the per capita CO_2 emmisions. This index is calculated as the complement of the equation 3.2 as can be seen in equation 3.3.

$$I_{emissions} = 1 - \frac{x - min}{max - min} = \frac{max - x}{max - min} \tag{3.3}$$

The final HSDI is then calculated as shown in equation 3.4

$$HSDI = \sqrt[4]{I_{life} \times I_{education} \times I_{income} \times I_{emissions}} \tag{3.4}$$

With these formulas all the dimensions hold the same weight ranging in value from 0 to 1. This method will serve as a reference to develop an index to evaluate the value adding systems from this perspective [96].

3.3.6.1 Economic

The economic component of the index will consist of two values. The first will be I_{risk} and the second the I_{NPV}. This will only be done on the scenarios that have a positive NPV and on which the risk analysis was done. The I_{risk} is calculated by utilizing the probability that a given scenario has a positive NPV. This value was calculated in the Monte Carlo simulation and is a percentage. The I_{NPV} is computed by using the NPV of each scenario as computed in the feasibility analysis. In each case *max* is the maximum value in the data set. The formulas in the discussion above serve as a guide, but if there is not set minimum value for each factor, the scenario with the smallest value will have an index value of zero. This is avoided by adapting the formulas as depicted in equation 3.5 and 3.6.

$$I_{risk} = \frac{x}{max} \tag{3.5}$$

$$I_{NPV} = \frac{x}{max} \tag{3.6}$$

3.3.6.2 Social

For the social dimension. It was decided to look at the jobs created by each scenario. The clause that served as the motivation for this reasoning was found in the Food and Agriculture Organization of the United Nations 8th Sustainable development goal. The goal is labelled: Decent work and economic growth. The clause states the following:

"Employment generation policies targeting rural youth would help rejuvenate the agricultural and rural work force and harness youth's energy and capacity to innovate. Better job prospects for the youth in rural areas would also contribute to reducing distressed migration to urban areas, where labour markets are often already saturated" [97]

It was therefore argued that from the social perspective of the project, it should generate as much work as possible. I_{jobs} is therefore calculated as depicted in equation 3.7. Where max is the maximum amount of jobs created by one of the scenarios in the data set.

$$I_{jobs} = \frac{x}{max} \tag{3.7}$$

3.3.6.3 Environment

For the environmental dimension of the index it was decided to look at the carbon credits that each scenario generates.

Climate change is considered to be one of the greatest threats to the future of humanity. To counter the effects of climate change it was decided to stabilize the level of atmospheric greenhouse gasses (GHGs) at 445-490 parts per million CO_2e (CO_2 equivalent or less. According to Yipping [98] forests have an important role to play in realizing this. In the process of transforming land with low levels of carbon (pasture lands, shrub, agricultural fields or degraded forests) into land that is forested land, which in turn contain carbon through vegetation and soil, more carbon can potentially be sequestered.

The Kyoto protocol provided nations three flexible options to decrease the cost of meeting emission targets.

1. Emission trading. This gives countries who have satisfied their targets and have excess allowances to sell it to other countries.
2. Joint Implementation: This entails the purchasing of emission credits from GHG offset projects in industrialized countries.
3. The Clean Development mechanism (CDM): This involves the purchase of emission credits from projects in non-industrialized countries. It permits developed countries to offset carbon dioxide through forestry or industry projects (reforestation, or afforestation). It offers

developing countries the opportunities to reduce its CO_2 trough receiving payment from developed countries. Currently there are 8 registered CDM forestry projects.

To give an indication of the amount of carbon that is sequestered by bamboo. Here are some of the results of research done on a Bambusa balcooa plantation. The research was done by Choudhury et al. [94]. The experiment was conducted on a plantation in its 5th year of age. The following data was obtained: 1.99 t per ha carbon in the leaf, 9.71 t per ha carbon in the branch, and 89.79 t per ha carbon in the culm. This adds up to 101.49 t per ha carbon in the AGB (above ground biomass), 8.51 t per ha carbon in the rhizome and 110 t per ha in the total biomass of Bambusa balcooa. This correlates with a total biomass of 246.13 ton per ha. (It must be remembered that only a certain amount of this can be harvested per year.)

The data is expressed in ton carbon sequestered per ha. The two types of scenarios that had a positive NPV where the 50 000 ton per ha and the 100 000 ton per ha. It was assumed that the carbon sequestered correlates with the amount of biomass. This means that in the Index calculations the 100 000 ton per ha will have an advantage over the 50 000 ton per ha scenario.
The index is only used to compare the scenarios with each other and is not some universal index.

$$I_{carbon} = \frac{x}{max} \tag{3.8}$$

With the situation at hand the max value used is 100 000 ton. Hence I_{carbon} will simply be 0.5 or 1 for the given scenario. The I_{carbon} index (calculated by equation 3.8) only looks at the size of the biomass or plantation to evaluate the scenarios. Yiping [98] states that the long-term storage of carbon is only possible when the culms are processed into products with long life cycles that are durable. This can include construction materials, furniture and panel products.

Another alternative is to use bamboo as a bio-energy resource which is an alternative to fossil fuel, charcoal products and biochar. According Yiping [98] this can provide additional opportunities to mitigate climate change.

The index can therefore be calculated with the following formula, equation 3.9. Each factor has the same weight in this formula. The results are discussed in section 4.3

$$Sustainable\ development\ index = \sqrt[4]{I_{NPV} \times I_{risk} \times I_{jobs} \times I_{carbon}} \tag{3.9}$$

3.4 Charcoal production.

Each of the value-adding methods are discussed as shown by the process flow chart in Figure 3-2. This method was followed to understand the input variables of each value-adding method and broadly covers each of the topics as depicted below. This section of the discussion starts off with charcoal.

The quotation was obtained from Gongyi Xiaoyi Mingyang Machinery Plant, which is situated in Gongyi City, China.

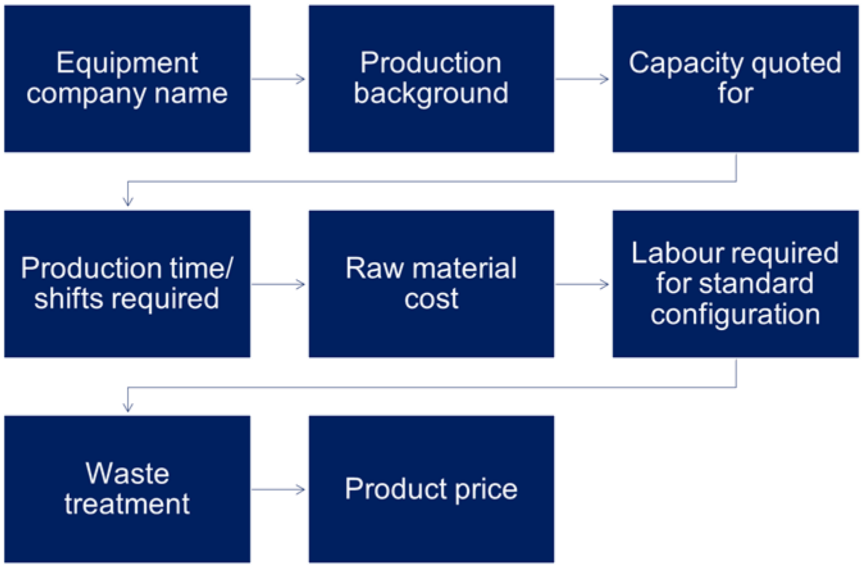


Figure 3-2: The Process flow diagram depicts each of the elements covered in the discussion below for each of the value adding systems.

The Yield of the charcoal is about 25% according to The National Mission on Bamboo Applications [53] and to 30% of the weight of the bamboo fed into the production process according to Liese [25]. Kwako [99] also works with a 30% yield. Therefore a 30% yield is used in the calculations.

The capacity for the standard configuration is 40 tons per day. To be able to facilitate this capacity, the carbonizer furnace has to operate 24 hours which is divided into 3 shifts. The rest of the plant needs only one 10 hour shift. The carbonizer section requires 4 workers per shift and the rest of the plant requires 15 workers per shift. The raw material cost is R 275.00 per ton [90].

When using wood as the source, all the waste produced in the charcoal production processed will be reused in the process. This was confirmed with Ignite [100] charcoal producers situated in KwaZulu-Natal. This is assumed to be the same for charcoal produced with bamboo as the biomass source.

The Product price was taken as R 4644.11 per ton excluding VAT and R 5294.29 per ton including VAT. This is the same price at which Ignite trade their Charcoal per ton [100], hence this is an excellent price estimate if the product produced, must compete on the local market.

3.5 Biochar

The quotation for the Biochar equipment was obtained from the same supplier as the charcoal machinery. The company's name is Gongyi Xiaoyi Mingyang Machinery Plant and they are situated in Gongyi City, China.

The BioChar production process is the least complicated and consists of two main parts, a carbonizing and crushing part. The quotation was constructed to be able to facilitate 33 tonnes of raw material if the carbonizer is to be operated 24 hours (three 8 hour shifts) and the crushing section for one 8 hour shift.
The BioChar process makes use of the raw bamboo provided by the farming operations at R275.00 per ton.

The amount of labourers required with the standard plant configuration as given in the quotation is 4 at the carbonizer section per shift and 4 on the crusher section per shift.
It is assumed that the waste treatment cost will be similar than the charcoal production facility, which is R 0.00 per ton.

To import Biochar will cost $580 (R7 889.20) per ton, which includes shipping. When import tax is included it amounts to R8798.52 per ton. The Biochar retail price according to Bam d'afrique in South Africa is R3000.00 per ton [90]. The latter price is used for the calculations.

3.6 Activated Carbon

The Quotation for the Activated Carbon plant was obtained from Shanghai Daiwo Machinery Technology Co. The plant includes all the necessary equipment for the activation process, but the plant does not include the equipment to carbonize the biomass. Due to this it is assumed that Biochar is used as a raw material to produce Activated Carbon. Therefore the selling price of Biochar is used as the cost of the raw material.

The equipment in the quote obtained is structured to produce 4.5 ton of activated carbon in a period of 24 hours. In this period it consumes 9.5 carbonized biomass to do so. About 12 – 14 labourers is needed to operate the plant with the capacity as mentioned in the quotation. To use this data to calculate the other scenarios it is scaled by using equation 2.1.

The Activated Carbon process also produces waste that had to be treated. The waste is mainly water that contains hydrochloric acid (HCl) which is used to wash the Activated Carbon after the activation process. 100 kg of HCl is used for every 1 ton of Activated Carbon produced. The waste is neutralised using 0.044 ton of lime per 1 ton of Activated Carbon produced. The Cost of the lime and the waste is all accounted for in the waste section of the model for all the Activated Carbon scenarios. These are the only inputs and outputs of the process according to the salesman at Shanghai Daiwo Machinery Technology Co.

The sales price of the Activated Carbon used in the calculations was obtained from Hebei Baisite Technology Co. The price used is the CIF Cape Town price, with import tax it is calculated at R28 531.97.

Locally ROTOCARB produces Activated Carbon for R 36480.00 incl. VAT. It was decided to use the lower price in the calculations to be more internationally competitive.

3.7 Laminated Board

The equipment to be used for the Laminated Board calculations are produced by Chin Yung Bamboo & Wood Co., LTD. The company was established in 1956, and they are specialists in the manufacturing of bamboo and wood working machinery. They are situated in Taiwan and is currently the largest exporter to South-East Asia.

The capacity of the production line as depicted in the quotation is a bit more complicated than the previous cases, but it is discussed below. The bamboo doesn't have to dry before it is used in the production process.

Considering a 16 hour production period the following production figures can be expected: 24 to 32 pieces of bamboo big board (1220mm x 2440mm x 40mm). The bamboo consumption for the amount of boards produced over that period of time is: 576 to 768 poles, 6m long, with a diameter of 10cm, a wall thickness of 7-8mm and, bamboo poles should be over 4 years of age. The centre of each interval will be used in the calculations. Therefore it is concluded that 672 poles gives 28 boards. Thus 24 poles are consumed to produce one 1220mm x 2440mm x 40mm board.

It is also assumed that 33% of the bamboo culm does not enter the manufacturing process as the 33% is used to manufacture something else like chopsticks. This means that 67% of the bamboo culm actually enters the production process. If it is reckoned that a Bambusa balcooa culm is on average 18 m tall, the question arose on what the length of the culm makes up 67% of the weight. It must be considered that the weight is not evenly distributed as a bamboo culm is tapered cylindrically. Bam d' afrique [90] suggested that one will be able to use 12 m if you consider a 20 m culm. Therefore it is assumed that 2 poles of 6 m each can be sourced from every culm.

To conclude we assume that one 1220mm x 2440mm x 40mm board needs 24 poles to be manufactured. Which suggests that 12 culms are needed to produce one board. This and the assumption that a culm weighs 52.5kg, which in turn is used to estimate the amount of boards that can be produced for each scenario. This is depicted in Table 3-5.

Table 3-5: This table shows quantity of boards that can be produced with each of the projected amounts biomass available.

Annual raw material availability [ton]	Boards per annum to be manufactured (rounded up)
500	794
1000	1588
2500	3486
5000	7937
10 000	15874
50 000	79366
100 000	158731

The amount of laborours required for the standard configuration, amounts to 35 labourers per 8 hour shift. The cost of the raw material is R 275.00 per ton. There is no cost for treating waste. The cost of the boards depends on the composition of the board. For example the Horizontal Pressed board is cheaper than the Cross Horizontal Pressed board. The overall approach to this project was more of a conservative nature and with this said it was decided to use the less expensive Horizontal Pressed board's price as a reference. The price used is the price of imported boards from Zhangzhou Pingxin Wood & Bamboo Co., China, which amounts to R2224.10 per board CIF Cape Town. This includes shipping and import Tax, but the shipping is a mere 4.4% of the total price. The current price for these boards in South Africa are R8205.72 including VAT.

3.8 Lang Factor input assumptions

The Lang factor is a fantastic method to obtain some study estimates for the project. Although in some instances it makes provision for costs that are not applicable to the specific scenario. In these instances, intuition and with consent of the study leader it was unanimously decided, which cost factors to discard and which to keep in the scenario. These changes are highlighted in Appendix B where it can be seen which factors was neglected at which scenarios.

3.9 Equipment Transport

The transport cost of the equipment is important to include in the calculations as the Lang factor method makes use of the delivered equipment cost to calculate the other costs. This includes the cost of the equipment as well as the cost of the transport from the equipment factory to the construction site. All the quotations for the equipment were obtained from companies situated in East Asia. Some of the quotations were quoted as the FOB price at the nearest port. Malbe a company that specializes in shipping, estimates the cost of shipping from most ports in Asia to South Africa as R49 500.00 for 20 feet containers and R61 000.00 for 40 feet containers. The domestic transport from Durban harbour to Klerksdorp, where the construction site is situated will be around R13 500.00.

Chapter 4 Results and discussion

4.1 Feasibility analysis results

The cumulated discounted cash flows at the end of the ten year period will be considered to determine whether a scenario is feasible or not. If the cumulated net annual discounted cash flows at end of the period are positive, the project is considered to be feasible. If the cumulated net annual discounted cash flows at end of the period are negative, the project is considered to be unfeasible and the analysis on the particular scenario will be ceased. The scenarios that are deemed feasible by the criteria proceeds to risk analysis.

4.1.1 Charcoal

The graph below depicts that the only scenario that will be feasible according to the study estimate is the scenario where 100 000 ton can be sourced per annum. The 50 000 ton per annum also has a positive gradient, but it does not break even in the set 10 year period. From Figure 4-1 it can be observed that the other scenarios have a downwards slope and will never break even.

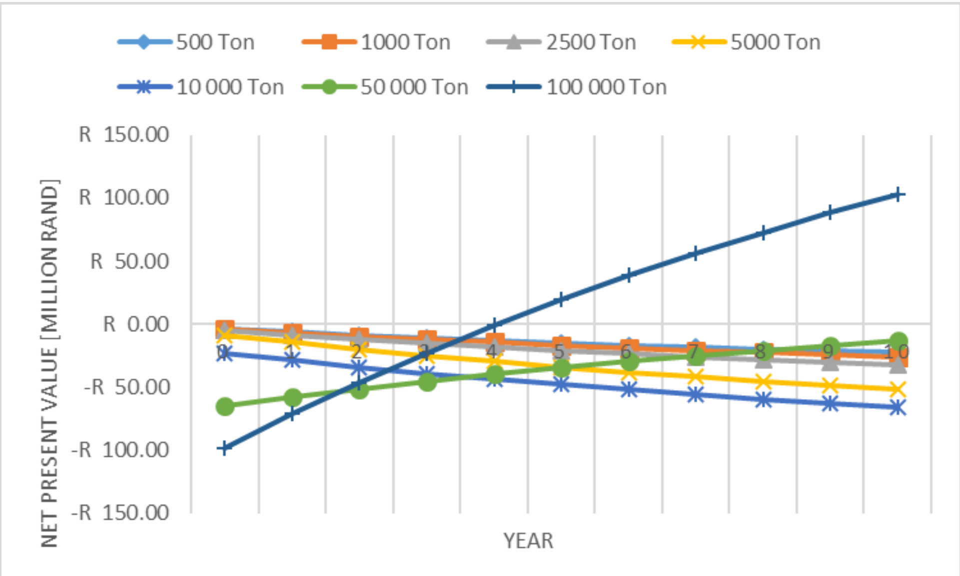


Figure 4-1: The NPV of each of the scenarios for the Charcoal value-adding system over a period of 10 years.

4.1.2 Biochar

For the Biochar value-creating system two of the scenarios proved to be feasible. Both the 50 000 ton per annum and the 100 000 ton per annum raw material availability were the only scenarios to have an upward slope. It can be seen from Figure 4-2 that the 100 000 ton scenario has a positive net annual cash flow from year two of operations and the 50 000 ton scenario has a positive net annual cash flow from year three of operations.

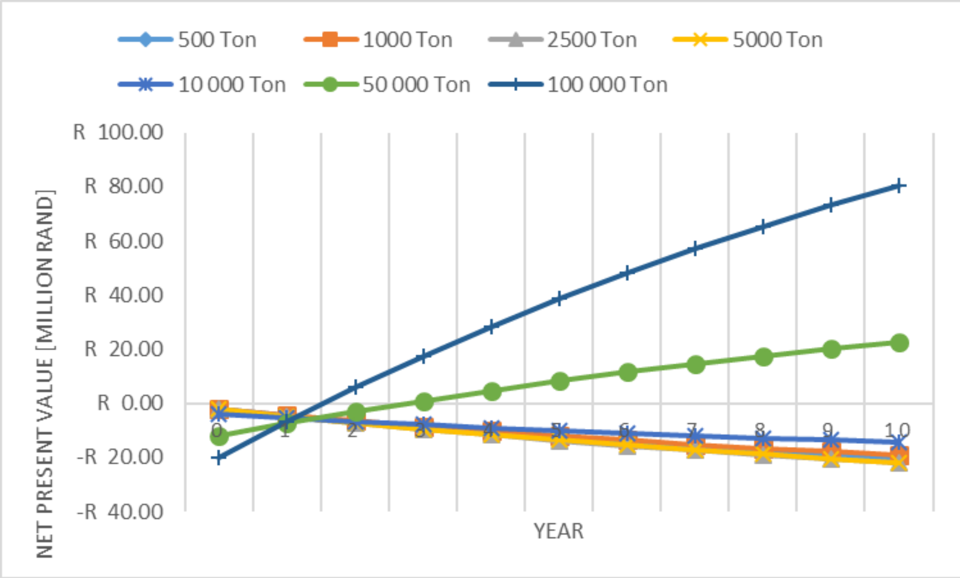


Figure 4-2: The NPV of each of the scenarios for the Biochar value-adding system over a period of 10 years.

4.1.3 Activated Carbon

The Activated carbon value-creating system has three scenarios that had a positive slope. The 10 000 ton, 50 000 ton and 100 000 ton scenarios. Only the 50 000 ton scenario and the 100 000 ton scenario breaks even within the 10 year period of time. From Figure 4-3 it is clear that the 50 000 ton and the 100 000 ton scenarios break even at year two of the operations.

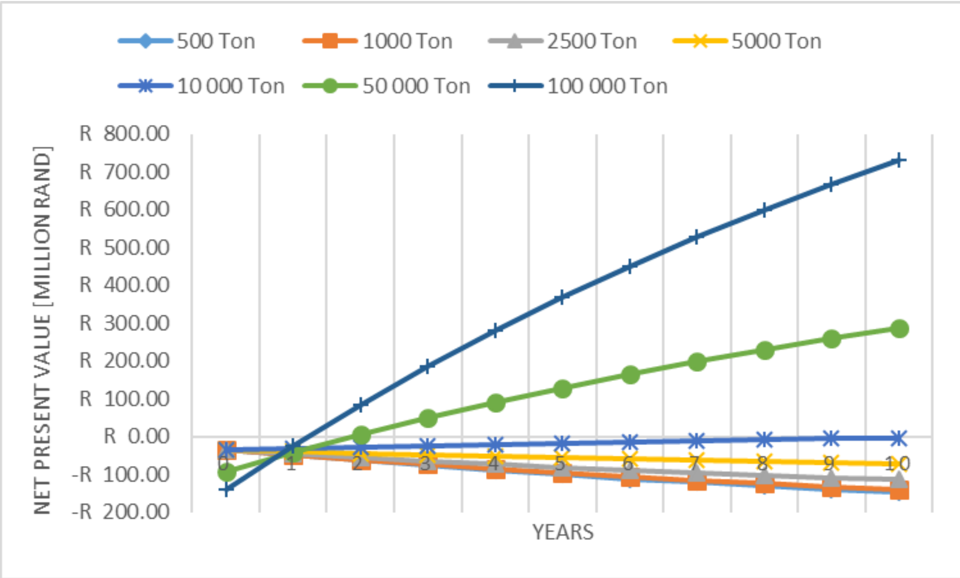


Figure 4-3: The NPV of each of the scenarios for the Activated Carbon value-adding system over a period of 10 years.

4.1.4 Laminated boards

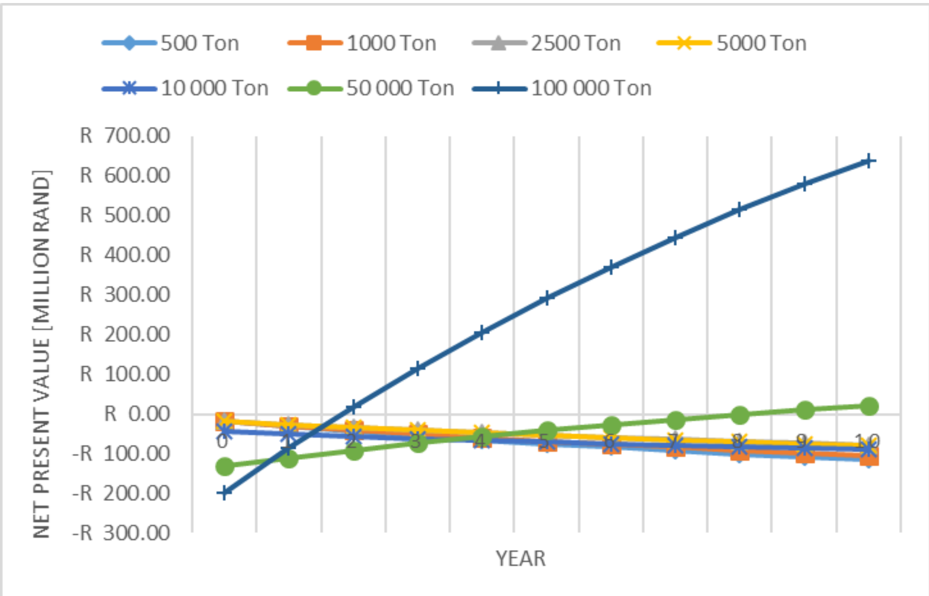


Figure 4-4: The NPV of each of the scenarios for the Laminated boards value adding system over a period of 10 years.

The Laminated board's value creating system has two scenarios that break even within the required period. The 100 000 ton scenario breaks even fairly early in year two of operations whilst the 50 000 ton scenario only breaks even in year 9 of the operations. All the other scenarios have a negative gradient as can be observed from Figure 4-4.

4.1.5 Comparison

Table 4-1 illustrates the NPV for each value adding system at each scenario and the NPV at the end of the 10 year project period. The red indicates that the scenario has a downward trend and will never break even. The yellow specifies that it will be able to break even, but not within the 10 year span of the project, and the year in which it breaks even, is stated. In these scenarios, it is assumed that all the cash flows have the same trend as in the previous 10 years. The green signifies that the scenario breaks even within the 10 year span and states when this takes place. As can be observed from the table below, in order to be competitive, it is better to enable economy of scale. Looking at the 100 000 ton scenarios, it can be seen that the Activated Carbon value-creating system has the highest cumulative net cash flow after ten years with an amount of R729 472 351.10. This is followed by Laminated Boards, with a value of R639 777 550.44, Charcoal, with a value of R102 872 143.29 and Biochar with a value of R80 512 521.32.

Table 4-1: This table shows the NPV for each value adding system at each scenario and the NPV at the end of 10 year.

Amount to be processed/Method 10 Year NPV	500 Ton	1000 Ton	2500 Ton	5000 Ton	10 000 Ton	50 000 Ton	100 000 Ton
10 Year NPV Charcoal	-R 22 623 893.28	-R 25 787 374.90	-R 32 066 493.14	-R 51 850 768.36	-R 65 668 530.51	-R 13 177 931.76	R 102 872 143.29
	Never	Never	Never	Never	Never	Year 15	Year 5
10 Year NPV Biochar	-R 20 574 012.96	-R 19 118 455.49	-R 21 939 686.23	-R 21 849 802.05	-R 14 352 405.71	R 22 509 246.76	R 80 512 521.32
	Never	Never	Never	Never	Never	Year 3	Year 2
10 Year NPV Activated Carbon	-R 147 150 635.53	-R 138 777 399.18	-R 113 657 690.11	-R 71 791 508.34	-R 2 593 485.85	R 286 591 314.90	R 729 472 351.10
	Never	Never	Never	Never	Year 12	Year 2	Year 2
10 Year NPV Laminated Board	-R 114 887 345.56	-R 103 752 636.31	-R 77 836 196.50	-R 79 581 483.06	-R 90 006 648.14	R 22 093 383.60	R 639 777 550.44
	Never	Never	Never	Never	Never	Year 9	Year 2

The graph below considers the net present value or the cumulative net discounted cash flows after 10 years. From this graph it can be seen that the Laminated Board value adding system has the highest Capex (Fixed Capital Investment) and the highest Opex (Cost of Manufacturing). The Laminated Board operations requires the most labour and in some instances more than 3 times more than the other value-adding systems. This contributes to the high Opex. The Activated Carbon value-adding system is ranked third when it comes to labour requirement, but it has the second largest Opex. This is due to the large cost of the raw material and the cost of waste treatment.

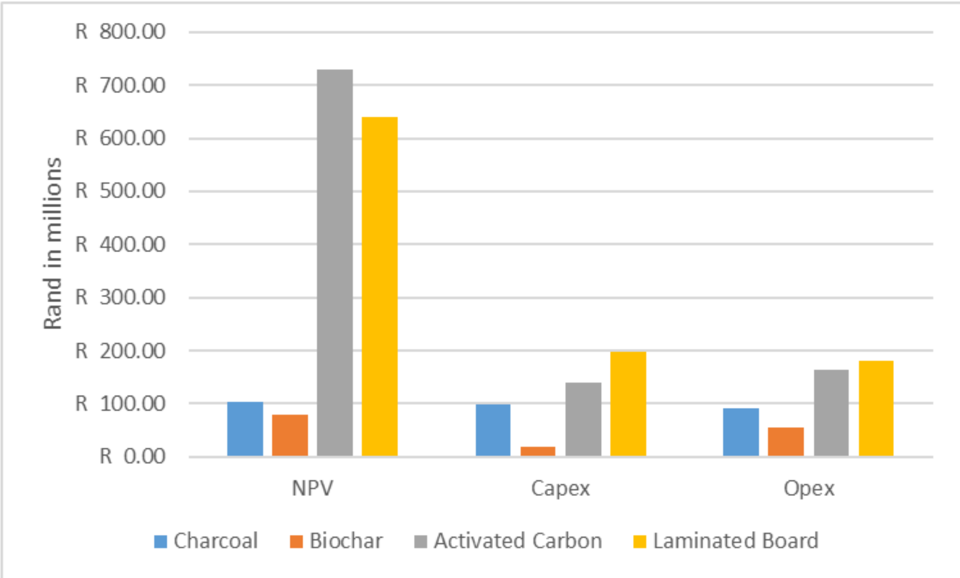


Figure 4-5: The NPV, Capex and Opex for each value adding system for the 100 000 ton scenario.

4.2 Risk analysis

@Risk software was used to do a risk analysis on the scenarios that were feasible in the feasibility analysis. The @Risk software runs a simulation by means of a Monte Carlo simulation. The @Risk tool enables a person to vary inputs by fitting a distribution to the inputs.

Some of the Lang factors has a minimum, midpoint and maximum value. For the feasibility analysis the midpoint was used in the calculations. In the risk analysis a triangular distribution was used to vary these inputs over the range of the minimum and maximum values with the midpoint value as the most likely value. The other values were either fitted with a normal or a triangle distribution.

At the end of the risk analysis the following was observed: 1) The probability that the scenario at hand has a positive NPV after 10 years (the probability for the cumulative net discounted cash flows after 10 years to be positive.) 2) The sensitivity of the model towards certain inputs are observed. The effect that the inputs have on the NPV are ranked on a tornado graph. The tornado graph present the inputs from the highest to the lowest influence on the NPV. Below the most important inputs that will be varied are stated. Most of these inputs are unique to each value-adding system.

- Price of the raw material
- Product selling price
- Wage cost
- Production Efficiency
- The Bulk FCI investment cost
- Interest rate
- Lang Factors

The full list of all the inputs are displayed in Appendix E.

4.2.1 Inputs Distributions

To determine the variation interval of the inputs, the following method was followed: If data was available, it was used as an input. This simply means that if there were other possible input values, such as a higher and a lower wage, it was used. In the case where there was no data available the variation interval as depicted in Table 2-9 was used. In such instances the present value was used as the most likely value. This implies the following:

The upper segment for the interval of a labourer in a factory was taken as R 101.39 per hour [101]. The Middle (or most probable)and lower interval was taken as R 46.48 and R 34.42 per hour [82]. These are respectively the base salary for a skilled Plant & System Operator and an Assembling & Fabricating labourer. The range over which the wage was varied is depicted in Figure 4-6.

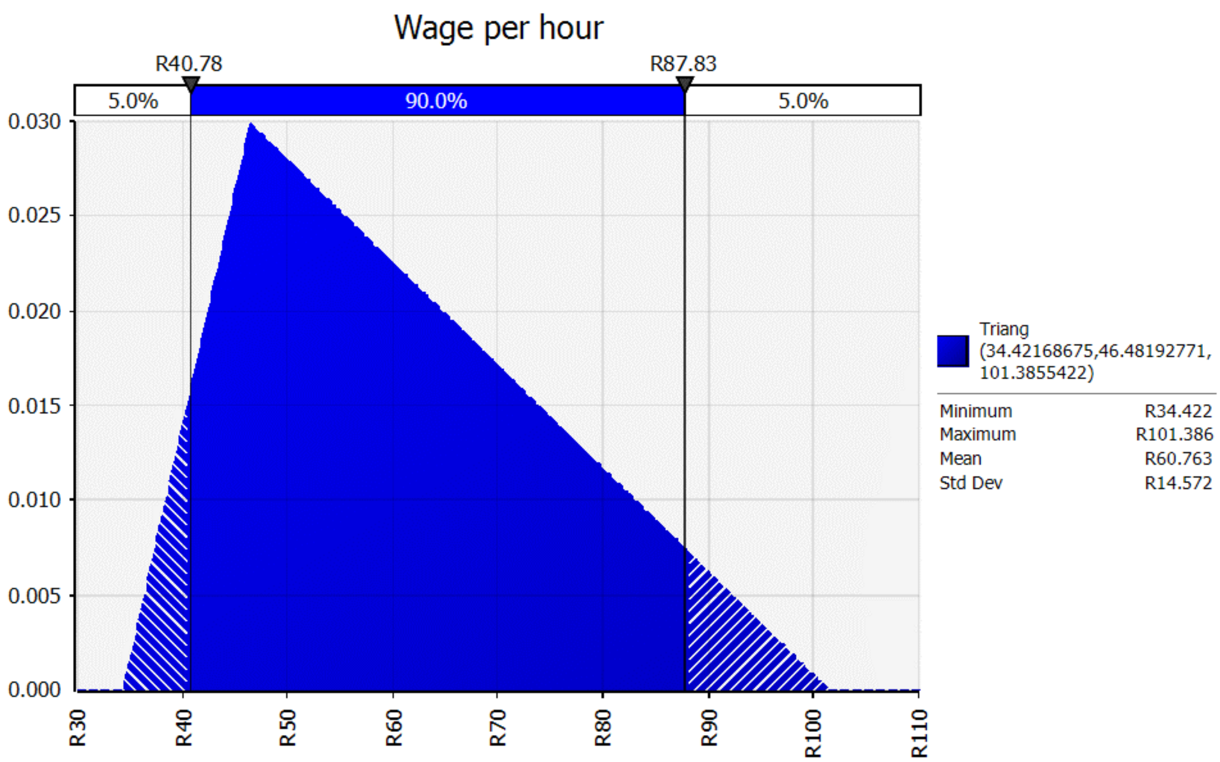


Figure 4-6: The input distribution of the wage cost per hour. This is the same for all 28 scenarios.

The historical data of the prime lending rate or interest rate was obtained from the South African reserve bank. This data stretches over a ten year period from 1 October 2007 to 1 October 2017. A Distribution was fitted to this data using the @Risk tool's fit distribution function. A normal distribution was fitted to the data as seen in Figure 4-7. The interest rate varies in factors of 25 basis points, therefore the distribution was rounded to 25%.

The Product selling price was varied differently for each value adding system.
The Charcoal price was varied from -50 % to +20% of the price used in the feasibility analysis. This variation is suggested by Turton [73].The minimum price for Biochar was also -50% of the normal price. The maximum price however was the sales price of Biochar from CFert. CFert sells biochar at R 5130.00 Inc. VAT. The minimum price for Activated Carbon was again -50% the normal price. The maximum price of Activated Carbon used in the simulation is the price per ton of the local producer RotoCarb. Their price is R36 480.00 per ton for about the same mesh size of Activated Carbon as used in the feasibility analysis.
The South African price for Laminated Bamboo Board is much higher than the price of imported boards from China or East Asia. If the product is to compete with the international market the price must therefore be lower and the quality higher. As previously mentioned, a conservative approach was taken on the project, hence the price in the feasibility analysis is almost four times less than the

maximum price used in the risk analysis. The maximum price used in the simulation is the South African price. The minimum price for the Activated Carbon is again -50 % of the normal price.

The raw material was varied in the range as suggested by Table 2-9. The range varies from -25% to 50% of the normal price. In accordance with the data provided by Table 2-9, the Fixed capital Investment or Capex was varied form -10% to 25%. The remaining Lang Factors are varied in the range provided by the multiply factors.

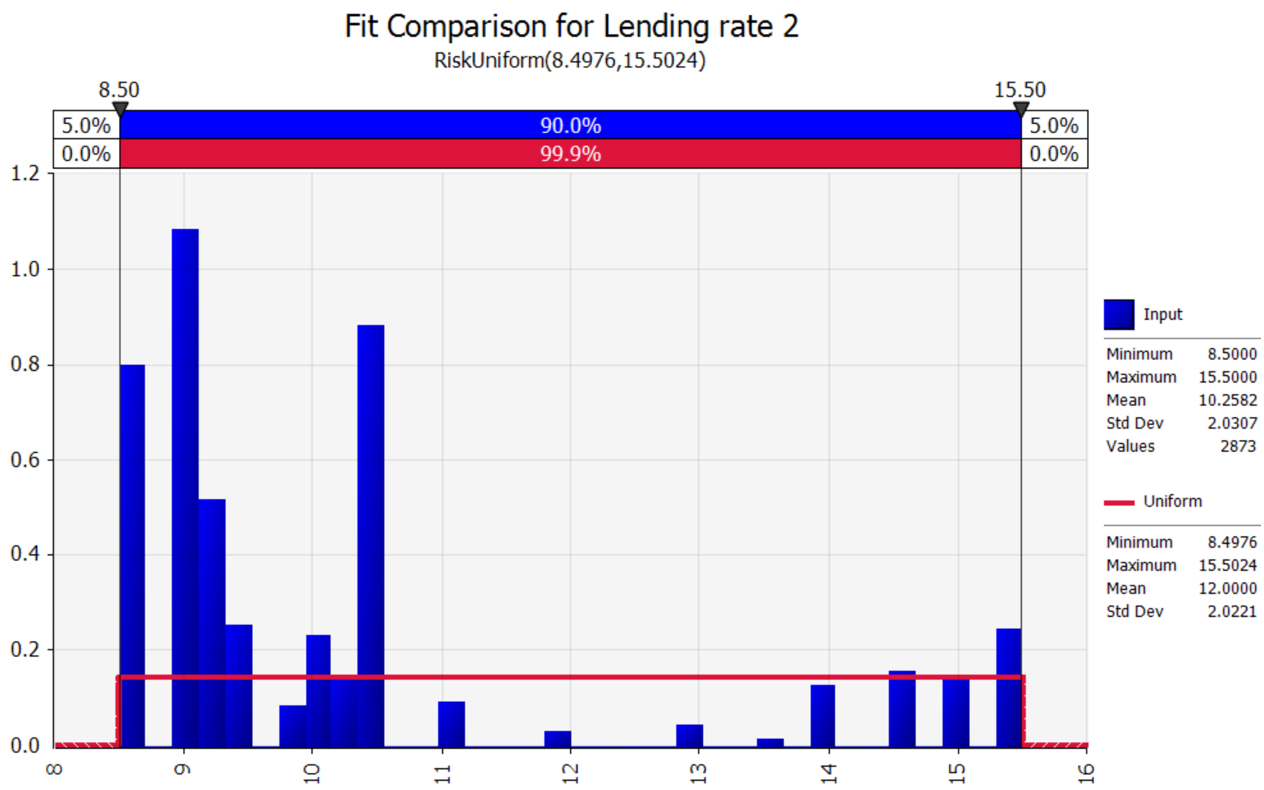


Figure 4-7: The normal distribution of the interest rate over a 10 year period.

The production efficiency was assumed to be 100% in the feasibility analysis. For the risk analysis it will be varied from 90 % as the minimum value, 95% the most likely and 100% as the maximum value.

4.2.2 Risk analysis results

Three simulations of 10000 iterations were run on each of the remaining scenarios. All the scenarios that had a positive NPV after the ten year evaluation period were considered in this risk analysis. These seven scenarios are listed below.

- Charcoal value-adding system in the case of a 100 000 ton annual bamboo yield.
- Biochar value-adding system in the case of a 100 000 ton annual bamboo yield.

- Biochar value-adding system in the case of a 50 000 ton annual bamboo yield.
- Activated Carbon value-adding system in the case of a 100 000 ton annual bamboo yield.
- Activated Carbon value-adding system in the case of a 50 000 ton annual bamboo yield.
- Laminated Board value-adding system in the case of a 100 000 ton annual bamboo yield.
- Laminated Board value-adding system in the case of a 50 000 ton annual bamboo yield.

In the discussion below two types of graphs are displayed. The first displays the probability density of each scenario.
On the Y – axis of the graph, the amount or fraction of the 10 000 iterations that falls within a certain interval, are displayed. On the X – axis the Net Present Value or cumulative net cash flows after the 10 year analysis period is displayed. At the top of the graph the probability of having a certain NPV is displayed. For all the cases, the probability of having a positive NPV are displayed. Thus, the percentage of iterations had a positive NPV. On the right hand side of each graph the minimum, maximum and mean of all the iterations are shown.

The second type of graph is called a tornado plot and forms part of the sensitivity analysis. It depicts the sensitivity that the scenario has to the varying inputs of each scenario. It ranks the inputs on the influence it has on the NPV of the particular scenario, from the highest to the least. It displays the effect the minimum and maximum value has on the NPV. This also highlights the inputs where special attention can be paid to increase the profitability of the project. The figures not displayed in this discussion can be seen in Appendix F.

4.2.2.1 Charcoal value adding system in the case of a 100 000 ton annual bamboo yield.

As can be seen in Figure 4-8 the probibility that the Charcoal 100 000 ton scenario will have a positive NPV is a mere 28 %, this is the lowest of all the scenarios in the simulation. Even the mean of the scenario is negative with a value of R96 million.

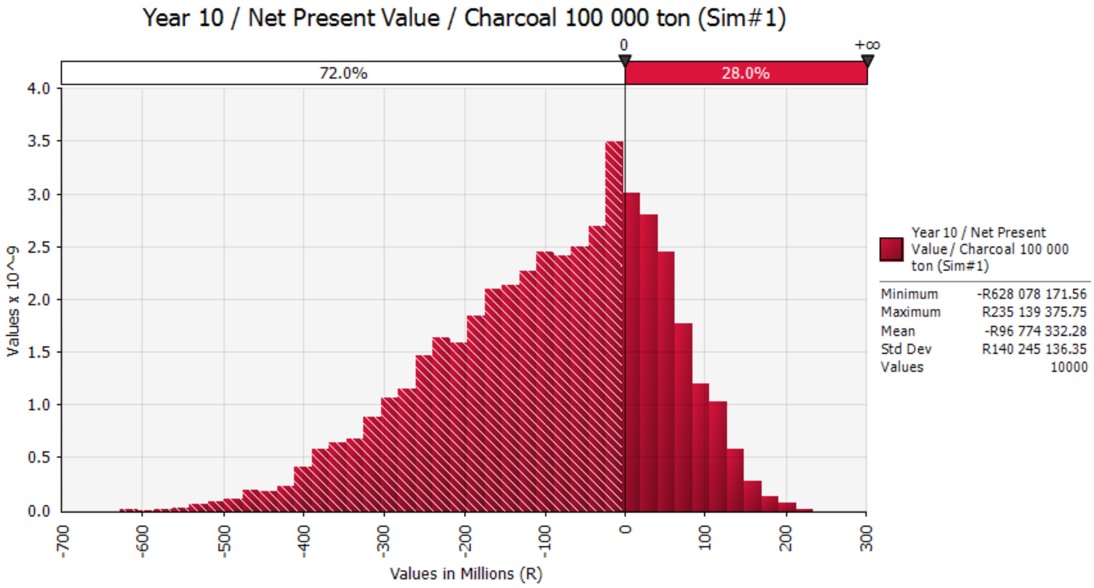


Figure 4-8: The probability distribution of the Charcoal value adding system for the 100 000 ton scenario.

The minimum possible NPV is -R628 million and the maximum NPV is R235 million. There is a 90% chance that the NPV will be between R355 million and R101 million.

In the tornado plot displayed in Appendix F it is clear that the selling price of the product has the greatest effect on the NPV. By varying the selling price from its minimum to maximum value the mean of the NPV can range from -R328 million to R73 million. This is followed by the wage per hour, raw material cost and the Fixed Capital Investment or Capex. An interesting observation highlights the fact that no other maximum values pushes the negative mean of the NPV to be positive. The only input capable of doing this is the product selling price.

4.2.2.2 Biochar value adding system in the case of a 100 000 ton annual bamboo yield.

The Biochar 100 000 ton scenario has a much higher chance of being profitable than the Charcoal 100 000 ton scenario. The probability that the project will have a positive NPV in this scenario is 66%. In the same breath it can be seen that there still is a 34% chance that the project will have a negative NPV after the 10 year project period. The minimum NPV is R315 million and the maximum is NPV R340 million. In contrast to the Charcoal 100 000 ton scenario, the mean NPV in this scenario is positive (Appendix F).

From the results it is clear that the product selling price has by far the greatest effect on the NPV of the model. This is followed by the raw material cost and the wage per hour, which has basically the same effect on the model. The minimum input values of the wage per hour, raw material and product selling price pulls the mean NPV to be negative, with the later input that can result in a mean NPV as low as -R140 million.

4.2.2.3 Biochar 50 000 Ton

The risk analysis on the Biochar 50 000 ton scenario shows that the NPV of the scenario can go either way. After the 10 year period it has a slightly more than 50 % chance to be negative, and a slightly less than 50% chance to be positive. The mean NPV is a relatively small negative value of R6.36 million, the minimum NPV is –R192 million and the maximum NPV is R153 million.

As in the 100 000 ton Biochar scenario, the product selling price again has the largest effect in this scenario. The effect on the mean NPV range from being –R99 million to R81 million. Mention must be made of the fact that the mean NPV of this scenario is negative, and therefore all the minimum inputs of the variables will result in a negative NPV.

4.2.2.4 Activated carbon 100 000

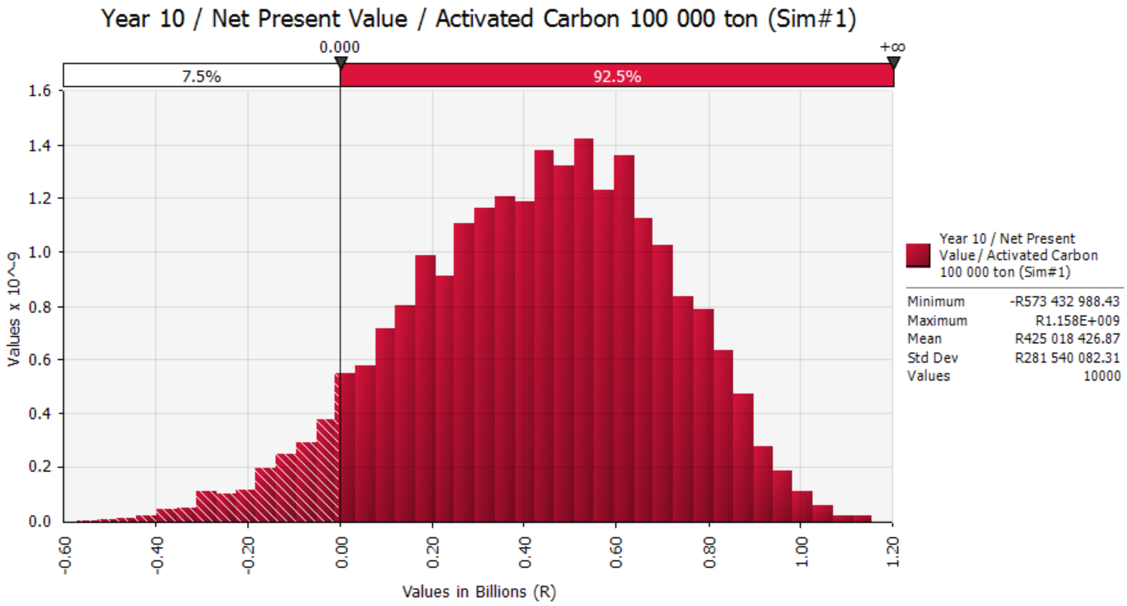


Figure 4-9: The probability distribution of the Activated Carbon value adding system for the 100 000 ton scenario.

From all the scenarios discussed up until now this scenario has the greatest probability to have a positive NPV after 10 years. It can be witnessed from Figure 4-9 that there is still a very small probability of 7.5% that the NPV can be negative but the 92.5% possibility of NPV to have a positive value far outweighs this small chance.

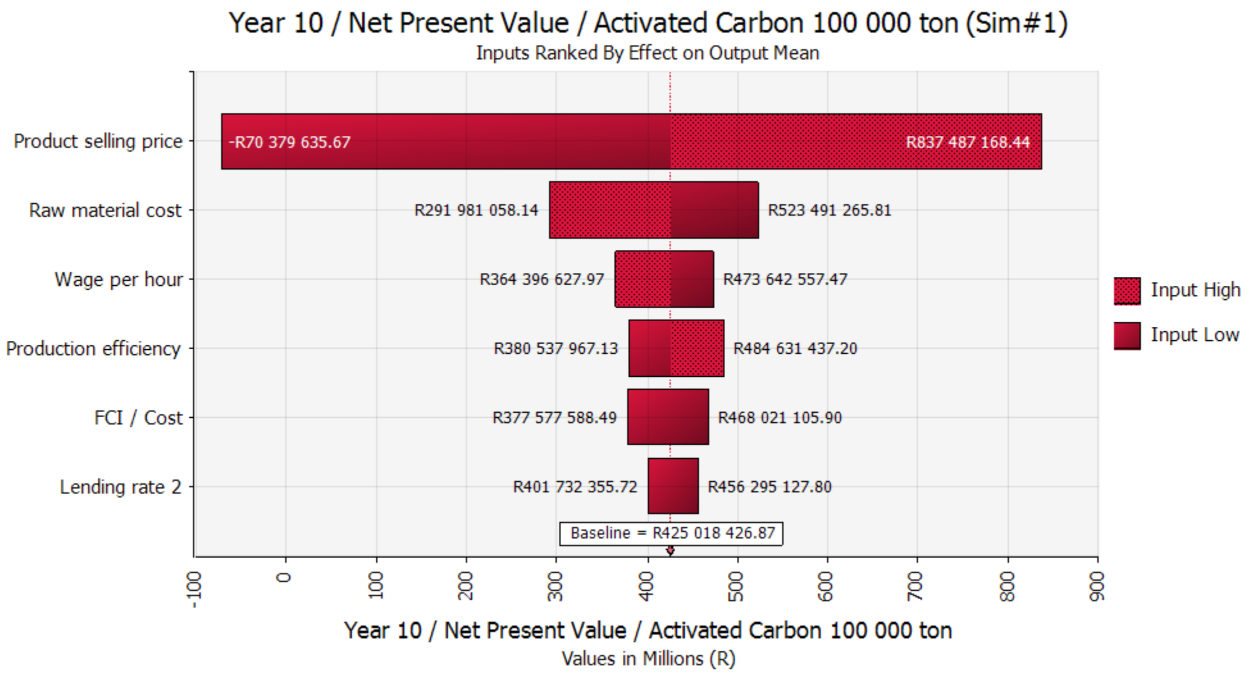


Figure 4-10: The tornado plot displays the sensitivity analysis for the Activated Carbon value adding system for the 100 000 ton scenario.

The mean NPV is R425 million and the minimum NPV is -R573 million and the maximum R1158 million. Only the minimum value of the product selling price can push the mean NPV to be negative. From Figure 4-10 it is clear that none of the other minimum inputs of the variables effect the NPV in such a way that it can become negative. This puts this scenario in a very solid position as the product selling price was already taken at a relatively low figure.

4.2.2.5 Activated carbon 50 000 ton

The Activated Carbon 50 000 ton scenario also appears to be a solid case with only a 19.8% probability of having a negative NPV. The mean NPV is positive with a value of R121 million. The maximum NPV is R539 million whilst the minimum NPV is -R457 million.

The product selling price has the greatest effect on the model by far. The raw material cost and wage per hour takes second and third place. As in the 100 000 ton Activated Carbon the product selling price is the only variable that causes the mean NPV to have a negative value. This makes, this scenario a very strong case as well.

4.2.2.6 Laminated board 100 000

Figure 4-11 depicts that the Laminated Board 100 000 ton has a mere 5.5% chance of having a negative NPV. One point of concern is that the minimum NPV can be as much as –R 1041 million. The other side of the coin however is that the positive NPV has a maximum value of R5156 million.

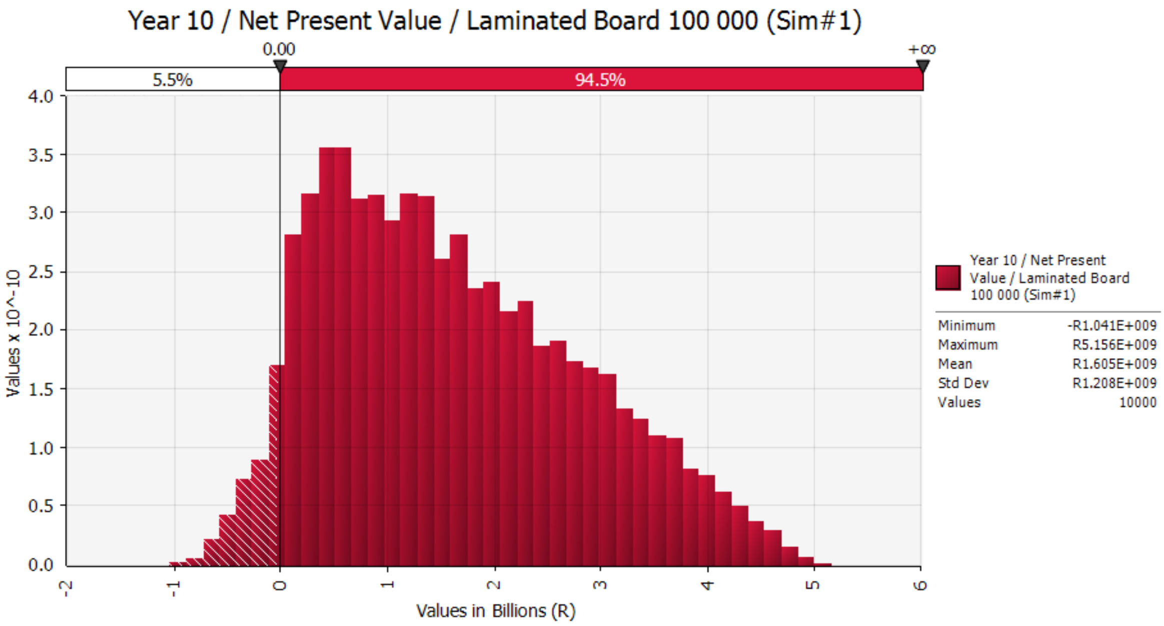


Figure 4-11: The probability distribution of the Laminated board value adding system for the 100 000 ton scenario.

This might appear to be faulty since the Activated Carbon scenarios in the comparative yield categories had a much larger NPV in the feasibility analysis. As mentioned in section 4.2.1 the maximum value input for the selling price was roughly four times more than the value used in the feasibility analysis. The maximum input price for these boards is the selling price in South Africa. This does not mean that the South African market is large enough to absorb the amount of boards produced in this scenario.

Due to the high mean value, all of the other input bars have a very high positive minimum value. As Figure 4-12. illustrates, the product selling price once again has the greatest effect on the model. The reason for this was explained in the paragraph above. Noticing from this figure, it can be concluded that the product selling price plays a definite role in the success of this scenario.

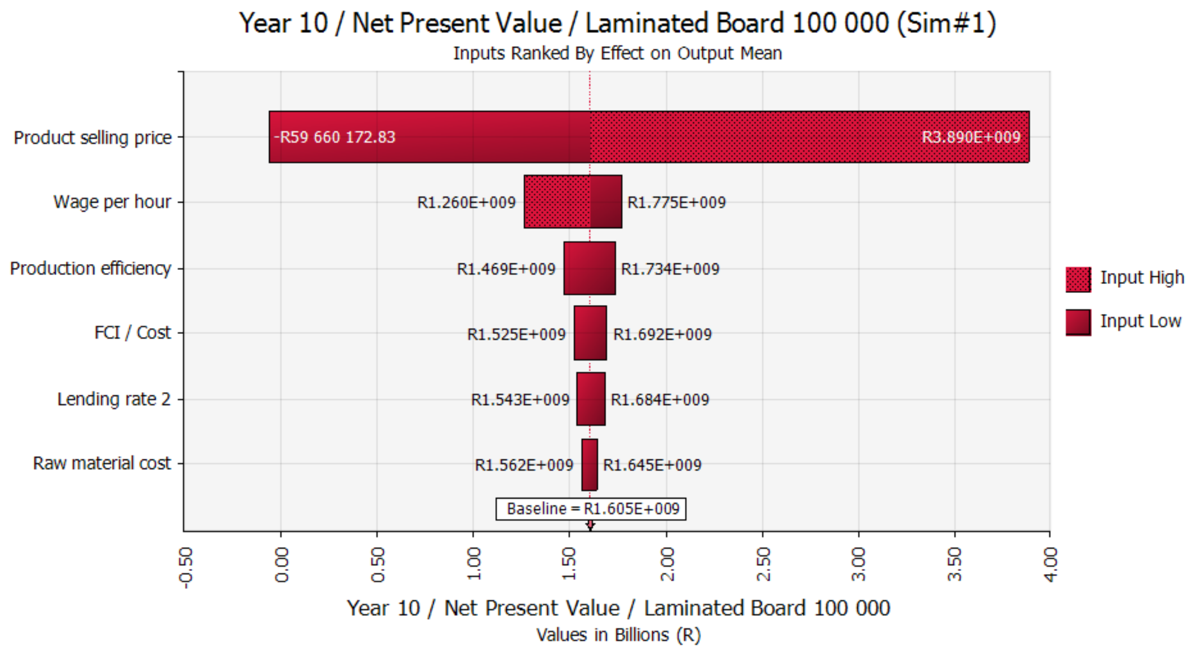


Figure 4-12: The tornado plot displays the sensitivity analysis for the Laminated board value adding system for the 100 000 ton scenario.

4.2.2.7 Laminated board 50 000

This scenario also has a very high probability of having a positive NPV, 84.3% to be specific. The mean NPV is positive and fairly high with a value of R613 million, the maximum value is very high with a value of R2 437 million. The minimum value has a quite high negative value of -R 812 million. This scenario is ranked third when comparing the probabilities of having a positive NPV and ranking the scenarios from having the highest to the lowest probability of having a positive NPV.

From observing Figure F-9 in Appendix F it is clear that as in all the previous scenarios considered in the risk analysis, the product selling price once again has the greatest effect on the outcome of the scenario. Except for the wage per hour, the other inputs, does not have such a big impact on the NPV. The product selling price can sway the mean NPV to have a negative value of -R 257 million.

4.3 The sustainable development index

This index is just to give an indication and is not to be used in other projects. It compares the three scenarios against each other at a few factors that can be argued to fall under the three pillars of sustainable development. Considering the index calculation's, which made use of equations to 3.3.5 to 3.3.9, the following results as portrayed in Table 4-2 where obtained.

Table 4-2: The results of the sustainable index calculations.

Scenario	NPV	Risk	Jobs created	Ton	I_{NPV}	I_{risk}	I_{job}	I_{carbon}	Index
Charcoal 100 000 ton	R 102 872 143.29	0.28	99	100 000	0.14	0.28	0.29	1.00	0.33
Biochar 100 000 ton	R 80 512 521.32	0.66	60	100 000	0.11	0.70	0.17	1.00	0.34
Biochar 50 000 ton	R 22 509 246.76	0.493	40	50 000	0.03	0.52	0.12	0.50	0.17
Activated Carbon 100 000 ton	R 729 472 351.10	0.925	81	100 000	1.00	0.98	0.23	1.00	0.69
Activated Carbon 50 000 ton	R 286 591 314.90	0.802	55	50 000	0.39	0.85	0.16	0.50	0.40
Laminated board 100 000 ton	R 639 777 550.44	0.945	346	100 000	0.88	1.00	1.00	1.00	0.97
Laminated board 50 000 ton	R 22 093 383.60	0.843	229	50 000	0.03	0.89	0.66	0.50	0.31

With the sustainable development index it was found that the Laminated board scenario consumes 100 000 ton of raw bamboo creates the most value when considering all three pillars of Sustainable value creation. It has a NPV of R639 777 550.44 has a probability of 94.5% to have a positive NPV. The scenario creates 346 jobs and it utilises a bamboo source that has a large amount of carbon credits. The scenario that scored the second highest was the Activated carbon 100 000 ton scenario. The scenario has a higher NPV than the scenario that scored the highest NPV. It has an NPV of R729 472 351.10, has a probability of 92.5% to have a positive NPV, creates 81 jobs and also utilises a bamboo source that has a large amount of bamboo credits.

Chapter 5 Conclusion

5.1 Research findings

This study made an attempt to promote the use of bamboo to rehabilitate the destruction left by mining activities and to create jobs for communities left behind by mines that ceased production activities. The study endeavours to find the best value adding method for bamboo, concerning the project at hand and within the limits of the defined scope.

The first goal of the study was to understand the value creation possibilities for Bamboo applications. Therefore a comprehensive study was done on different applications of bamboo. The plant offers promising opportunities as a source of biomass for several applications. With advice from industry and the guidance of the project study leader, it was decided to focus on 4 applications, or value-creations or adding systems as they were referred to in the study. The following four value-creating systems were explored: Bamboo Charcoal, Bamboo Biochar, Bamboo Activated Carbon and Bamboo Laminated Board.

The second goal of the study was to identify the key elements to consider and the bamboo supply capacity for the project. Bamboo is a plant or type of grass to be more specific which means that its characteristics and behaviour is volatile for example when cultivated and exposed to different conditions. Assumptions based on research where made to be able to define bamboo's characteristics and behaviour. There are for example different projected yields of biomass produced per annum per hectare. There is also not much information for cultivating bamboo in the South African climate. Therefore certain scenarios had to be developed to make provision for the varying, unpredictable and unknown. The fluctuating moisture content of the bamboo had to be considered since it has an effect on the product quality and production volume estimates. These are just some of the factors that had to be considered in this project.

Develop a financial study estimate model that considers different developingt sizes and phases, was the third goal of the study and with the help of good process design sources and past research documents a financial model was built that provided an 'easy-to-use' platform. The model was adjusted for each of the four value-creating systems and then again for each of the seven scenarios of these systems. This added up to 28 scenarios or financial models. The financial model is based on what is known as a 'study estimate' of the capital cost for the projected project. The Lang factor method forms an integral part of the financial model. The method helps to predict the cost of an entire project by multiplying the equipment cost with certain factors.

All the information acquired and work done to finish the previous research objectives were combined to satisfy the fourth research objective. The fourth goal read as follows: To validate the financial study estimate model with selected bamboo value creation systems based on the key elements and supply capacity to identify feasible solutions. In addition to the work done to complete the previous research goals, quotations were obtained from industry. These quotation served as a reference and was adapted to each scenario. To obtain these quotations proved to be a challenge. Many companies where not motivated to assist in supplying the quotations if they suspected that there weren't any money to be made from the time they spent in constructing the quotations. A different strategy had to be followed to obtain the quotations and this in turn proved to be successful.
A feasibility analysis were done on each scenario once the 28 scenarios were set up. Seven of the scenarios had a positive NPV. In the feasibility study the Activated Carbon 100 000 ton had the highest NPV with an amount of R 729 472 351.10. it breaks even in year 2. Second to this is the 100 000 ton laminated board scenario which has an NPV of R 639 777 550.44 and it also breaks even in year 2. The 100 000 ton Activated Carbon scenario has a lower Capex and Opex than the 100 000 ton Laminated Board scenario. If the remaining scenarios were to be ranked by the NPV value they will have the following order: 3) 50 000 ton Activated Carbon, 100 000 ton Charcoal, 100 000 ton Biochar, 50 000 ton Biochar and last 50 000 ton Laminated Board. A risk analysis was done on each of these seven scenarios to determine which scenario is the best fit for the set criteria. This is the fifth and last goal for the study.

A Monte Carlo simulation was done on each of the seven scenarios. Important inputs were varied, and the possible range of the multiplication factors for each cost element was also varied. The simulation was done with @Risk software. The results proved to be very interesting. The Activated Carbon 100 000 ton scenario which had the highest positive NPV in the feasibility analysis had a probability of 92.5 % to a have positive NPV with a mean NPV of R425 018 426.87. The 100 000 ton Laminated Board scenario had a higher mean NPV of R1 600 million and a higher probability of 94.5% to have a positive NPV. As in the feasibility analysis these two scenarios performed the best in the risk analysis. The credibility of the results in the real world depends on whether the laminated boards can sell at the upper limit product price that was used in the risk analysis. This price is the product selling price in South Africa and had a big effect on the outcome of the risk analysis. This price is very high and it is perhaps not realistic to think that a large volume of the product will actually sell at this price. The Activated Carbon perhaps has a more realistic price interval in the risk analysis. But the Laminated Board scenario also performed the best in the sustainable development index creating 346 jobs, 265 more jobs than the 100 000 ton Activated Carbon scenario. Considering all above mentioned and to conclude this study with all the assumption made and from the viewpoint of sustainable development. This study suggests that a Laminated Board value creation system with access to 100 000 ton of raw bamboo per annum is the best option for the given project. May the research done contribute to South Africa's economic growth and create shared value for both the mining companies and communities in which mines operate

5.2 Future Work and final remarks

The level of detail of this study is knwona study estimate which means that the project can be 72% over the budget and 48% below budget. A class one or detailed estimate budget will not be more than 6% and less than 4% of the calculated cost, which opens room for improvement. If a detailed cost estimate is to be done in the future it, will probably require more than one student or master project to determine such an estimate.

This project serves as a good solid foundation, and proves to be sound background knowledge on bamboo and a lot of knowledge was gained from the project. The project methodology and general framework can also be used in future work.

The approach to industry would be different in the future. Companies from abroad are not as helpful as local companies when it came to providing information for the project. Local companies value the institution of Stellenbosch University and it was easier to work with them. A strict business approach should be taken when contacting companies abroad. If the companies suspected that they could make money they were quite helpful. Working with Chinese companies posed an additional language challenge and in some instances several emails had to be sent in order to obtain the desired information. INBAR has great resources but they were very helpful when it came to answering questions or when general assistance was required.

Over all the project was an enlightening learning experience. Helpful knowledge and skillsets were gained in several areas.

Reference List

[1] W. E. Geil, *A Yankee on the Yangtze: Being a Narrative of a Journey from Shanghai through the Central kingdom to Burma*. A.C. Armstrong and Son, 1904.

[2] B. N. Kigomo, "Bamboo Resource in the East Africa Region," in *Bamboos Current Research*, 1988, pp. 22–28.

[3] A. A. Ogunjinmi, H. M. Ijeomah, and A. A. Aiyeloja, "Socio-Economic Importance of Bamboo (Bambusa Vulgaris) in Borgu Local Government Area of Niger State , Nigeria," *J. Sustain. Dev. Africa*, vol. 10, no. 4, pp. 284–298, 2009.

[4] R. Baxter, "Mining In South Africa: The Challenges and The Opportunities," 2016.

[5] S. Emec, P. Bilge, and G. Seliger, "Design of production systems with hybrid energy and water generation for sustainable value creation," *Clean Technol. Environ. Policy*, vol. 17, no. 7, pp. 1807–1829, 2015.

[6] L. Monostori, "CIRP Annals - Manufacturing Technology Value creation and decision-making in sustainable society," vol. 58, pp. 681–700, 2009.

[7] H. Schmutzenhofer, "The IUFRO Position on Sustainable Management of Tropical Forests," in *Forest Codes of Practice: Contributing to Environmentally Sound Forest Operations*, 1996, pp. 22–31.

[8] H. Brundtland, "Report of the World Commission on Environment and Development : Our Common Future," 1987.

[9] E. Westkamper *et al.*, "CIRP Annals - Manufacturing Technology The incoming global technological and industrial revolution towards competitive sustainable manufacturing," vol. 57, pp. 641–659, 2008.

[10] I. S. Jawahir, "The Driving Force for Innovative Products, Processes and Systems for Next Generation Manufacturing," 2006.

[11] F. Jovane *et al.*, "The incoming global technological and industrial revolution towards competitive sustainable manufacturing," *CIRP Ann. - Manuf. Technol.*, vol. 57, no. 2, pp. 641–659, 2008.

[12] H. Zhang, J. Calvo-Amodio, and K. R. Haapala, "A conceptual model for assisting sustainable manufacturing through system dynamics," *J. Manuf. Syst.*, vol. 32, no. 4, pp. 543–549, 2013.

[13] M. C. Howard, "Sustainable Manufacturing Initiative (SMI): A True Public-Private Dialogue." The U.S. Department of Commerce.

[14] A. D. Jayal, F. Badurdeen, O. W. Dillon, and I. S. Jawahir, "Sustainable manufacturing: Modeling and optimization challenges at the product, process and system levels," *CIRP J. Manuf. Sci. Technol.*, vol. 2, no. 3, pp. 144–152, 2010.

[15] A. Huang, *a Framework and Metrics for Sustainable Manufacturing Performance Evaluation at the Production Line , Plant and Enterprise levels*. University of Kentucky, 2017.

[16] A. Neely, C. Adams, and P. Crowe, "The performance prism in practice," *Meas. Bus. Excell.*, vol. 5, no. 2, pp. 6–13, 2001.

[17] A. Huang and F. Badurdeen, "Sustainable Manufacturing Performance Evaluation: Integrating Product and Process Metrics for Systems Level Assessment," *Procedia Manuf.*, vol. 8, no. October 2016, pp. 563–570, 2017.

[18] B. M. E. Dannenmann *et al.*, "The Potential of Bamboo as a Source of Renewable Energy in Northern Laos," in *Conference on International Agricultural Research for Development*, 2007, no. ii, pp. 50–53.

[19] K. Salam, "Bamboo for Economic Prosperity and Ecological Security," 2008.

[20] H. Ahsan, A. Ali, and R. Ali, "Oxygen free radicals and systemic autoimmunity," *Clin. Exp. Immunol.*, vol. 131, no. 3, pp. 398–404, 2003.

[21] M. Goleniowski and M. Bonfill, "Natural Products," no. January, 2013.

[22] O. Hidalgo-López, *Bamboo the gift of the gods*, 1 edition. Bogotá (Colombia), 2003.

[23] M. D. Burger, G. A. Oosthuizen, J. F. Oberholzer, P. De Wet, and C. I. Ras, "Strategies to Standardise Bamboo for Manufacturing Process Chains," *Procedia Manuf.*, vol. 8, no. October 2016, pp. 330–337, 2017.

[24] J. Moyo, "Bamboo – An Answer to Deforestation or Not in Africa?," *Inter Press Service*, 2015. [Online]. Available: http://www.ipsnews.net/2015/02/bamboo-an-answer-to-deforestation-or-not-in-africa/. [Accessed: 09-Nov-2017].

[25] W. Liese and M. Kohl, *Bamboo: The Plant and its Uses*, First. Heidelberg: Springer International Publishing , 2015.

[26] Y. Agyei, "Deforestation in Sub-Saharan Africa," *African Technol. Forum*, vol. 8, no. 1, 1998.

[27] P. van der Lugt, A. A. J. F. van den Dobbelsteen, and J. J. A. Janssen, "An environmental, economic and practical assessment of bamboo as a building material for supporting structures," *Constr. Build. Mater.*, vol. 20, no. 9, pp. 648–656, 2006.

[28] P. Chaowana, "Bamboo: An Alternative Raw Material for Wood and Wood-Based Composites," *J. Mater. Sci. Res.*, vol. 2, no. 2, 2013.

[29] J. M. O. Scurlock, D. C. Dayton, and B. Hames, "Bamboo: An overlooked biomass resource?," *Biomass and Bioenergy*, vol. 19, no. 4, pp. 229–244, 2000.

[30] M. Lobovikov, S. Paudel, M. Piazza, H. Ren, and J. Wu, "World bamboo resources: A thematic study prepared in the framework of the Global Forest Resources, assessment 2005," *FAO Tech. Pap.*, pp. 1–74, 2007.

[31] M. Lobovikov, D. Schoene, and L. Yping, "Bamboo in climate change and rural livelihoods," *Mitig. Adapt. Strateg. Glob. Chang.*, vol. 17, no. 3, pp. 261–276, 2012.

[32] W. Liese, "Anatomy and Properties of Bamboo," in *Recent Research on Bamboo*, 1985, pp. 196–208.

[33] P. Van der Lugt and J. G. Vogtländer, "The Environmental Impact of Industrial Bamboo

Products," 2015.

[34] T. R. Sonderstrom and R. P. Ellis, "Taxonomic status of the endemic South African bamboo, Thamnocalamus tessellatus," *Bothalia*, vol. 14, pp. 53–67, 1982.

[35] EcoPlanet, "EcoPlanet Bamboo South Africa," 2012. [Online]. Available: https://www.ecoplanetbamboo.za.com/. [Accessed: 14-Nov-2017].

[36] M. Bramley, "Bathurst - The centre of the universe," *Plaastoe*, 2016. [Online]. Available: http://www.plaastoe.co.za/dorpe/item/369-bathurst-the-centre-of-the-universe. [Accessed: 14-Nov-2017].

[37] P. Joubert, "ECDC looking to consolidate province's position as premier bamboo grower.," *Eastern Cape Development Corporation*, 2013. [Online]. Available: http://www.ecdc.co.za/media-centre/news/eastern-cape-as-bamboo-grower/. [Accessed: 15-Nov-2017].

[38] C. Macaskill, "Bamboo," *The Agri Handbook*, 2017. [Online]. Available: http://www.agrihandbook.co.za/index.php/book/forestry-industrial-crops/bamboo?showall=&start=1. [Accessed: 15-Nov-2017].

[39] Sa Forestry magazine, "Bamboo brings new oppertunities to SA," *Sa Forestry magazine*, 2014. [Online]. Available: https://docs.wixstatic.com/ugd/9df54b_f68427927ec74d4d87d1dc7fd2b9f0c4.pdf. [Accessed: 15-Nov-2017].

[40] G. Dunbar, "Commercial Bamboo Farming," *Brightfields*, 2017. [Online]. Available: http://www.brightfields.co.za/bamboo-farming/. [Accessed: 21-Nov-2017].

[41] S. Schröder, "Bambusa balcooa," *Guadua Bamboo*, 2011. [Online]. Available: https://www.guaduabamboo.com/species/bambusa-balcooa. [Accessed: 09-Nov-2017].

[42] S. Satya, L. M. Bal, P. Singhal, and S. N. Naik, "Bamboo shoot processing: food quality and safety aspect (a review)," *Trends Food Sci. Technol.*, vol. 21, no. 4, pp. 181–189, 2010.

[43] N. Chongtham, M. S. Bisht, and S. Haorongbam, "Nutritional Properties of Bamboo Shoots: Potential and Prospects for Utilization as a Health Food," *Compr. Rev. Food Sci. Food Saf.*, vol. 10, no. 3, pp. 153–168, 2011.

[44] G. Chuanyou, "On Examining and Probing the History of the Chinese Bamboo Paper," *J. Bamboo Res.*, vol. 2, 2002.

[45] G. M. Chu *et al.*, "Effects of bamboo charcoal and bamboo vinegar as antibiotic alternatives on growth performance, immune responses and fecal microflora population in fattening pigs," *Anim. Sci. J.*, vol. 84, no. 2, pp. 113–120, 2013.

[46] Y. X. Chen *et al.*, "Effects of bamboo charcoal and bamboo vinegar on nitrogen conservation and heavy metals immobility during pig manure composting," *Chemosphere*, vol. 78, no. 9, pp. 1177–1181, 2010.

[47] J. Lehmann and S. Joseph, *Biochar for Environmental Management: Science, Technology*

and Implementation, Second. New York: Routledge, 2015.

[48] M. H. Duku, S. Gu, and E. Ben Hagan, “Biochar production potential in Ghana—A review,” *Renew. Sustain. Energy Rev.*, vol. 15, no. 8, pp. 3539–3551, Oct. 2011.

[49] M. Van der Merwe, “NewCarbon,” *NewCarbon*, 2017. [Online]. Available: http://www.newcarbon.co.za/. [Accessed: 16-Nov-2017].

[50] J. Konz, B. Cohen, and A. Van der Merwe, “Assessment of the potential to produce biochar and its application to South African soils as a mitigation measure,” 2015.

[51] J. Shenxue, “Training manual of bamboo charcoal for producers and consumers,” *Bamboo Eng. Res. Center, Nanjing For. Univ.*, pp. 1–54, 2004.

[52] X. Li, B. Lei, Z. Lin, L. Huang, S. Tan, and X. Cai, “The utilization of bamboo charcoal enhances wood plastic composites with excellent mechanical and thermal properties,” *Mater. Des.*, vol. 53, pp. 419–424, 2014.

[53] National Mission on Bamboo Applications, “Bamboo-based Charcoal Production,” New Delhi.

[54] M. Kwaku, “Bamboo as sustainable biomass Energy: A suitable alternative for firewood and Charcoal Production in Africa,” 2010.

[55] K. Hosokawa, *Bamboo Charcoal*. Bangkok: International Tropical Timber Organization, 2005.

[56] R. S. Zhao, X. Wang, X. Wang, J. M. Lin, J. P. Yuan, and L. Z. Chen, “Using bamboo charcoal as solid-phase extraction adsorbent for the ultratrace-level determination of perfluorooctanoic acid in water samples by high-performance liquid chromatography-mass spectrometry,” *Anal. Bioanal. Chem.*, vol. 390, no. 6, pp. 1671–1676, 2008.

[57] Greenyarn, “Benefits of Bamboo Charcoal,” 2005. [Online]. Available: http://www.greenyarn.com/benefits.htm. [Accessed: 20-Nov-2017].

[58] A. Bhatnagar, W. Hogland, M. Marques, and M. Sillanpää, “An overview of the modification methods of activated carbon for its water treatment applications,” *Chem. Eng. J.*, vol. 219, pp. 499–511, 2013.

[59] B. H. Hameed and M. I. El-Khaiary, “Equilibrium, kinetics and mechanism of malachite green adsorption on activated carbon prepared from bamboo by K2CO3 activation and subsequent gasification with CO2,” *J. Hazard. Mater.*, vol. 157, no. 2–3, pp. 344–351, 2008.

[60] Q.-S. Liu, T. Zheng, N. Li, P. Wang, and G. Abulikemu, “Modification of bamboo-based activated carbon using microwave radiation and its effects on the adsorption of methylene blue,” *Appl. Surf. Sci.*, vol. 256, no. 10, pp. 3309–3315, 2010.

[61] B. Hameed, A. Din, and A. Ahmad, “Adsorption of methylene blue onto bamboo-based activated carbon: Kinetics and equilibrium studies,” *J. Hazard. Mater.*, vol. 141, no. 3, pp. 819–825, 2007.

[62] M. Ghauri, M. Tahir, and T. Abbas, “Production of activated carbon from Acacia Arabica sawdust,” *Int. J. Appl. Res.*, vol. 1, no. I, pp. 30–36, 2012.

[63] M. Parthiban, “Bamboo Charcoal Yarns/ Fabrics- A New Era in Textile Field,”

Fibre2Fasion.com. [Online]. Available: http://www.fibre2fashion.com/industry-article/3902/bamboo-charcoal-yarns-fabrics-a-new-era-in-textile-field. [Accessed: 20-Nov-2017].

[64] K. K. H. Choy, J. P. Barford, and G. McKay, “Production of activated carbon from bamboo scaffolding waste—process design, evaluation and sensitivity analysis,” *Chem. Eng. J.*, vol. 109, no. 1–3, pp. 147–165, 2005.

[65] I. . Sulastiningsih and Nurwati, “Physical and Mechanical properties of Laminated Bamboo Board,” *J. Trop. For. Sci.*, vol. 21, no. 3, pp. 246–251, 2009.

[66] H. T. Li, Q. S. Zhang, D. S. Huang, and A. J. Deeks, “Compressive performance of laminated bamboo.,” *Composites Part B: Engineering*, vol. 54, no. 1. pp. 319–328, 2013.

[67] P. Mahdavi, P. L. Clouston, and S. R. Arwade, “Development of Laminated Bamboo Lumber: Review of Processing, Performance, and Economical Considerations,” *J. Mater. Civ. Eng.*, vol. 26, no. 23, pp. 1036–1042, 2011.

[68] B. Sharma, A. Gatoo, M. Bock, H. Mulligan, and M. Ramage, “Engineerd bamboo: state of the art,” in *ICE proceedings*, 2014.

[69] National Bamboo Mission, “Manual for Establishment and management of bamboo plantations,” 2015.

[70] A. J. Huxley, M. Griffiths, and Royal Horticultural Society (Great Britain), *Dictionary of gardening*. Macmillan Press, 1992.

[71] R. Perry, D. Green, and J. Maloney, *Perry’s chemical engineers’ handbook*, no. 7th. 1997.

[72] J. Frederik and W. Durr, “A Feasibility Study for Titanium Recycling in South Africa by,” no. December, 2016.

[73] J. A. S. Richard Turton, Richard C. Bailie, Wallace B. Whiting, *Analysis, Synthesis and Design of Chemical Processes Third Edition*, vol. 53, no. 9. 2013.

[74] D. R. Seider, W.D. Seader, J.D. Lewin, “Product and Process Design Principles - Synthesis, Analysis, and Evaluation.” pp. 505–556, 2003.

[75] M. S. Peters, K. D. Timmerhaus, and R. E. West, *Plant Design and Economics for Chemical Engineers*. 1991.

[76] Palisade Corporation, “@RISK: Risk Analysis Software using Monte Carlo Simulation for Excel - at risk - Palisade,” 2017. [Online]. Available: http://www.palisade.com/risk/. [Accessed: 09-Nov-2017].

[77] Trading Economics, “South Africa Prime Overdraft Rate | 1957-2017 | Data | Chart | Calendar.” [Online]. Available: https://tradingeconomics.com/south-africa/bank-lending-rate. [Accessed: 08-Jun-2017].

[78] SARS, “Taxation in South Africa,” 2015.

[79] Exchange-Rates.org, “Exchange-Rates.org,” 2017. [Online]. Available: http://www.exchange-rates.org/history/ZAR/USD/G/M. [Accessed: 12-Jun-2017].

[80] Eskom, *Eskom Tariffs and Charges 2017/2018*. 2017.

[81] "Business days calculator in South Africa," 2017. [Online]. Available: http://south-africa.workingdays.org/#a3. [Accessed: 15-Jun-2017].

[82] BussinessTech, "South Africa's salaries: what people earn," 2014. [Online]. Available: https://businesstech.co.za/news/general/71195/south-africas-salaries-what-people-earn/. [Accessed: 05-Sep-2017].

[83] Jonathan Ramayia, "NERSA allows yearly 8% electricity price increase for 2013-2018 | Urban Earth," 2013. [Online]. Available: http://www.urbanearth.co.za/articles/nersa-allows-yearly-8-electricity-price-increase-2013-2018. [Accessed: 12-Oct-2017].

[84] Green Building Council, "Water Tariffs Rising Faster Than Electricity Prices, Inflation | GBCSA," 2014. [Online]. Available: https://www.gbcsa.org.za/news_post/water-tariffs-rising-faster-than-electricity-prices-inflation/. [Accessed: 12-Oct-2017].

[85] ENCA, "Municipal rates increases kick in," 2016. [Online]. Available: https://www.enca.com/south-africa/municipal-rates-increases-kick-in. [Accessed: 12-Oct-2017].

[86] Stanlib, "SA wage growth estimated at 7.7% in 2015 compared with an average inflation rate of 4.6%. The growth in real household income during 2015 supported retail sales, but this is likely to reverse in 2016," 2016. [Online]. Available: http://www.stanlib.com/EconomicFocus/Pages/SAwagegrowthestimatedat77in2015comparedwithanaverageinflationrateof46.aspx. [Accessed: 12-Oct-2017].

[87] K. Salam and N. K. Deka, *Training Manual On Nursery Raising, Commercial Plantation, Preservation And Primary Processing Of Bamboo*. Assam: Cane and Bamboo Technology Centre, 2007.

[88] B. K. Pandey, Y. C. Tripathi, and P. Hazarika, *A hand book of Propagation Cultivation & Management of Bamboo*. Jorhat: Rain Forest research Institute, 2008.

[89] S. Kumar, "Bamboo Technical Support Group (Indian Council of Forestry Research and Education)," 2014.

[90] P. Pearce, "Bam d'afrique," 2017. [Online]. Available: http://www.bda.hk/index.html. [Accessed: 19-Nov-2017].

[91] "Beema Bamboo: Beema/Bheema Bamboo." [Online]. Available: https://beemabamboo.blogspot.co.za/p/beema-bamboo.html?m=1. [Accessed: 25-May-2017].

[92] R. Govett, T. Mace, and S. Bowe, "A practical guide for the determination of moisture content of woody biomass," p. 20, 2010.

[93] S. Fu, M., Yang, X., Jiany, *Technical manual on Utilization of Sympodial Bamboos*. 2007.

[94] H. Choudhury *et al.*, "Carbon sequestration through Bhaluka Bamboo (Bambusa balcooa)," vol. 33, no. 3, 2015.

[95] D. D. Moran, M. Wackernagel, J. A. Kitzes, S. H. Goldfinger, and A. Boutaud, “Measuring sustainable development - Nation by nation,” *Ecol. Econ.*, vol. 64, no. 3, pp. 470–474, 2008.

[96] G. Bravo, “The Human Sustainable Development Index: New calculations and a first critical analysis,” *Ecol. Indic.*, vol. 37, no. PART A, pp. 145–150, 2014.

[97] Food and Agriculture Organization of the United Nations, “SDG 8. Decent work and economic growth,” *Sustainable Development Goals*, 2017. [Online]. Available: http://www.fao.org/sustainable-development-goals/goals/goal-8/en/. [Accessed: 15-Nov-2017].

[98] L. Yiping, L. Yanxia, K. Buckingham, G. Henley, and Z. Guomo, “Bamboo and Climate Change Mitigation: a comparative analysis of carbon sequestration,” *Inbar*, no. 32, 2010.

[99] G. Michael Kwaku, “Bamboo Biomass Energy –A Partnership between.” Kumasi, 2014.

[100] Steve Donaldson, “Ignite Charcoal Products,” 2017. [Online]. Available: http://www.igniteonline.co.za/. [Accessed: 22-Nov-2017].

[101] Trading Economics, “South Africa Average Monthly Wages in Manufacturing | 2004-2017 | Data,” 2017. [Online]. Available: https://tradingeconomics.com/south-africa/wages-in-manufacturing. [Accessed: 16-Jun-2017].

Appendix A Moisture content experiment

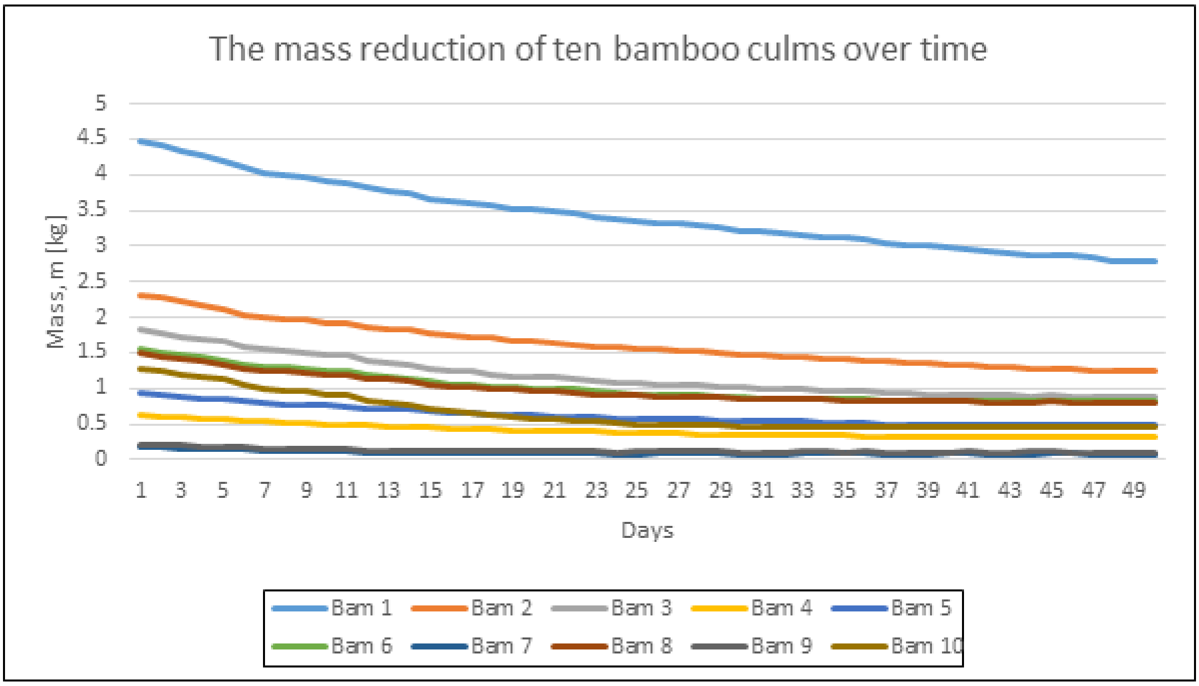


Figure A-1:The loss in moisture of ten bamboo samples over a period of 50 days

Appendix B Lang Factor adjustments

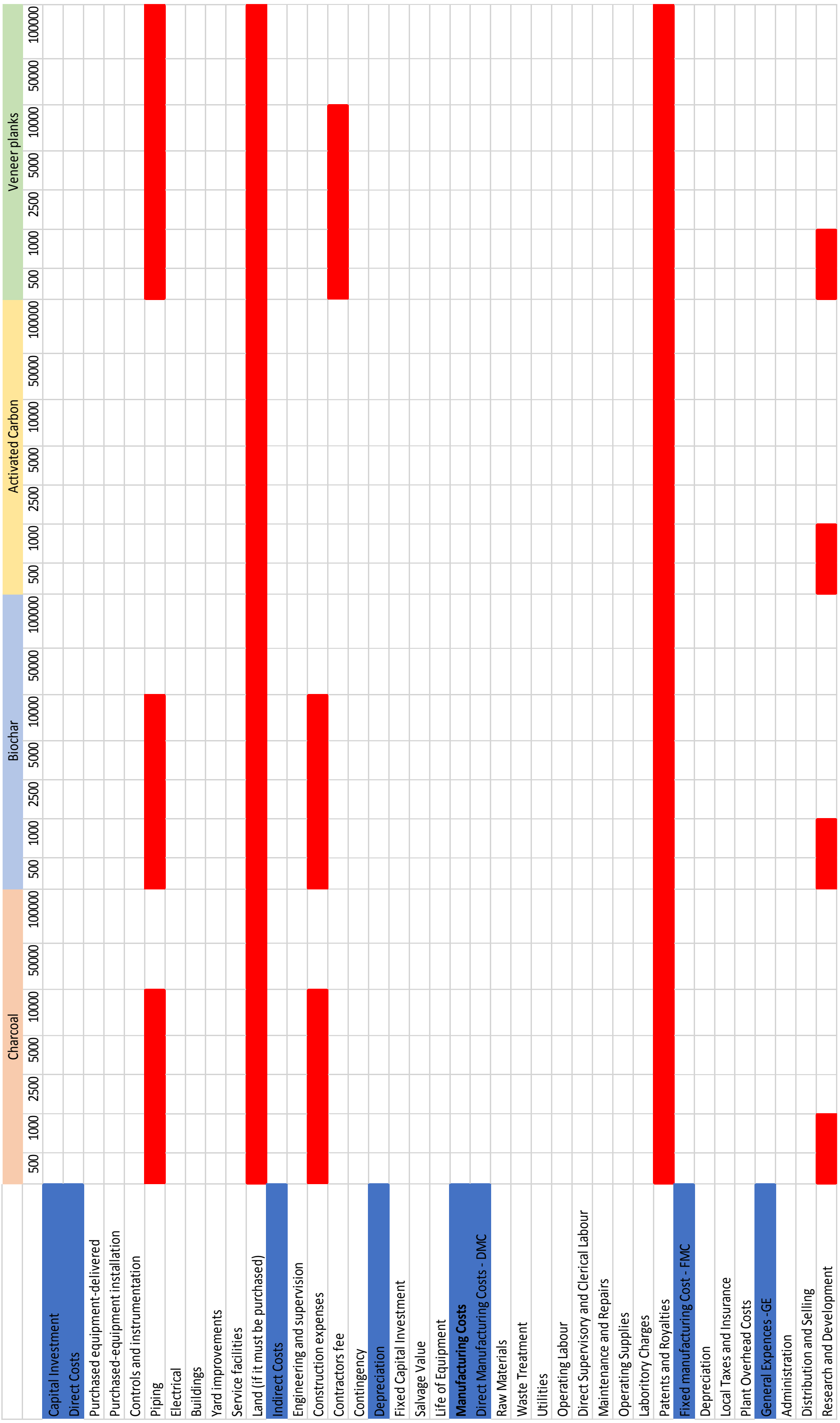


Figure A-1: The Adjustments done to the Lang factor in red.

Appendix C Feasibility Model Inputs

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 1 086 048.07
Purchased-equipment installation	0.45	0.39	0.47	R 423 558.75
Controls and instrumentation	0.09	0.13	0.18	R 141 186.25
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 108 604.81
Buildings	0.25	0.29	0.18	R 314 953.94
Yard improvements	0.13	0.1	0.1	R 108 604.81
Service facilities	0.4	0.55	0.7	R 597 326.44
Land (if it must be purchased)	0.06	0.06	0.06	
				R 2 780 283.06
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 347 535.38
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 195 488.65
Contingency	0.34	0.36	0.42	R 390 977.31
				R 934 001.34
FCI				R 3 714 284.41
Initial Loan Amount - P				R 3 714 284.41
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 10 565 763.43
Payment Amount per period - A				R 50 118.70
Total Annual amount				R 601 424.35
Depreciation				R 371 428.44
Fixed Capital Investment				R 3 714 284.41
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 1 372 853.98
Raw Materials				R 137 500.00
Waste Treatment				R 0.00
Utilities				R 120 277.56
Operating Labour				R 648 144.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 113 425.20
Maintenance and Repairs	0.02	0.1	0.06	R 222 857.06
Operating Supplies	0.1	0.2	0.15	R 33 428.56
Laboritory Charges	0.1	0.2	0.15	R 97 221.60
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 1 080 941.30
Depreciation			0.1	R 371 428.44
Local Taxes and Insurance	0.014	0.05	0.032	R 118 857.10
Plant Overhead Costs	0.5	0.7	0.6	R 590 655.76
General Expences -GE				R 491 578.85
Administration			0.15	R 147 663.94
Distribution and Selling	0.02	0.2	0.11	R 343 914.91
Research and Development			0.05	
Cost of Manufacturing - COM				R 3 126 499.15
Cost of Manufacturing without depreciation - COM_d				R 2 755 070.71
Income				R 664 192.17

Figure C-1: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 500 ton Charcoal scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 1 155 560.97
Purchased-equipment installation	0.45	0.39	0.47	R 450 668.78
Controls and instrumentation	0.09	0.13	0.18	R 150 222.93
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 115 556.10
Buildings	0.25	0.29	0.18	R 335 112.68
Yard improvements	0.13	0.1	0.1	R 115 556.10
Service facilities	0.4	0.55	0.7	R 635 558.53
Land (if it must be purchased)	0.06	0.06	0.06	
				R 2 958 236.09
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 369 779.51
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 208 000.98
Contingency	0.34	0.36	0.42	R 416 001.95
				R 993 782.44
FCI				R 3 952 018.53
Initial Loan Amount - P				R 3 952 018.53
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 11 242 028.95
Payment Amount per period - A				R 53 326.56
Total Annual amount				R 639 918.73
Depreciation				R 395 201.85
Fixed Capital Investment				R 3 952 018.53
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 1 953 357.82
Raw Materials				R 275 000.00
Waste Treatment				R 0.00
Utilities				R 178 824.54
Operating Labour				R 925 920.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 162 036.00
Maintenance and Repairs	0.02	0.1	0.06	R 237 121.11
Operating Supplies	0.1	0.2	0.15	R 35 568.17
Laboritory Charges	0.1	0.2	0.15	R 138 888.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 1 316 712.71
Depreciation			0.1	R 395 201.85
Local Taxes and Insurance	0.014	0.05	0.032	R 126 464.59
Plant Overhead Costs	0.5	0.7	0.6	R 795 046.27
General Expences -GE				R 659 939.97
Administration			0.15	R 198 761.57
Distribution and Selling	0.02	0.2	0.11	R 461 178.41
Research and Development			0.05	
Cost of Manufacturing - COM				R 4 192 530.97
Cost of Manufacturing without depreciation - COM_d				R 3 797 329.12
Income				R 1 328 384.34

Figure C-2: Capex and Opex inputs as well as Loan payment and Depreciation calculations for 1000 ton Charcoal scenario.

Capital Investment Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 1 535 803.24
Purchased-equipment installation	0.45	0.39	0.47	R 598 963.26
Controls and instrumentation	0.09	0.13	0.18	R 199 654.42
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 153 580.32
Buildings	0.25	0.29	0.18	R 445 382.94
Yard improvements	0.13	0.1	0.1	R 153 580.32
Service facilities	0.4	0.55	0.7	R 844 691.78
Land (if it must be purchased)	0.06	0.06	0.06	
				R 3 931 656.29
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 491 457.04
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 276 444.58
Contingency	0.34	0.36	0.42	R 552 889.17
				R 1 320 790.78
FCI				R 5 252 447.07
Initial Loan Amount - P				R 5 252 447.07
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 14 941 266.51
Payment Amount per period - A				R 70 873.89
Total Annual amount				R 850 486.71
Depreciation				R 525 244.71
Fixed Capital Investment				R 5 252 447.07
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 3 380 923.73
Raw Materials				R 687 500.00
Waste Treatment				R 0.00
Utilities				R 368 054.48
Operating Labour				R 1 481 472.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 259 257.60
Maintenance and Repairs	0.02	0.1	0.06	R 315 146.82
Operating Supplies	0.1	0.2	0.15	R 47 272.02
Laboritory Charges	0.1	0.2	0.15	R 222 220.80
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 1 926 848.87
Depreciation			0.1	R 525 244.71
Local Taxes and Insurance	0.014	0.05	0.032	R 168 078.31
Plant Overhead Costs	0.5	0.7	0.6	R 1 233 525.85
General Expences -GE				R 1 398 531.18
Administration			0.15	R 308 381.46
Distribution and Selling	0.02	0.2	0.11	R 749 477.93
Research and Development			0.05	R 340 671.79
Cost of Manufacturing - COM				R 6 813 435.75
Cost of Manufacturing without depreciation - COM_d				R 6 288 191.05
Income				R 3 320 960.84

Figure C-3: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 2500 ton Charcoal scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 2 517 644.80
Purchased-equipment installation	0.45	0.39	0.47	R 981 881.47
Controls and instrumentation	0.09	0.13	0.18	R 327 293.82
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 251 764.48
Buildings	0.25	0.29	0.18	R 730 116.99
Yard improvements	0.13	0.1	0.1	R 251 764.48
Service facilities	0.4	0.55	0.7	R 1 384 704.64
Land (if it must be purchased)	0.06	0.06	0.06	
				R 6 445 170.69
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 805 646.34
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 453 176.06
Contingency	0.34	0.36	0.42	R 906 352.13
				R 2 165 174.53
FCI				R 8 610 345.22
Initial Loan Amount - P				R 8 610 345.22
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 24 493 243.04
Payment Amount per period - A				R 116 183.69
Total Annual amount				R 1 394 204.29
Depreciation				R 861 034.52
Fixed Capital Investment				R 8 610 345.22
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 6 203 839.54
Raw Materials				R 1 375 000.00
Waste Treatment				R 0.00
Utilities				R 676 878.12
Operating Labour				R 2 685 168.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 469 904.40
Maintenance and Repairs	0.02	0.1	0.06	R 516 620.71
Operating Supplies	0.1	0.2	0.15	R 77 493.11
Laboritory Charges	0.1	0.2	0.15	R 402 775.20
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 3 339 581.44
Depreciation			0.1	R 861 034.52
Local Taxes and Insurance	0.014	0.05	0.032	R 275 531.05
Plant Overhead Costs	0.5	0.7	0.6	R 2 203 015.87
General Expences -GE				R 2 513 188.43
Administration			0.15	R 550 753.97
Distribution and Selling	0.02	0.2	0.11	R 1 349 173.69
Research and Development			0.05	R 613 260.77
Cost of Manufacturing - COM				R 12 265 215.38
Cost of Manufacturing without depreciation - COM_d				R 11 404 180.86
Income				R 6 641 921.68

Figure C-4: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 5000 ton Charcoal scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 6 708 012.41
Purchased-equipment installation	0.45	0.39	0.47	R 2 616 124.84
Controls and instrumentation	0.09	0.13	0.18	R 872 041.61
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 670 801.24
Buildings	0.25	0.29	0.18	R 1 945 323.60
Yard improvements	0.13	0.1	0.1	R 670 801.24
Service facilities	0.4	0.55	0.7	R 3 689 406.82
Land (if it must be purchased)	0.06	0.06	0.06	
				R 17 172 511.76
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 2 146 563.97
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 1 207 442.23
Contingency	0.34	0.36	0.42	R 2 414 884.47
				R 5 768 890.67
FCI				R 22 941 402.43
Initial Loan Amount - P				R 22 941 402.43
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 65 259 792.85
Payment Amount per period - A				R 309 559.81
Total Annual amount				R 3 714 717.68
Depreciation				R 2 294 140.24
Fixed Capital Investment				R 22 941 402.43
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 8 404 044.21
Raw Materials				R 2 750 000.00
Waste Treatment				R 0.00
Utilities				R 298 542.14
Operating Labour				R 2 847 204.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 498 260.70
Maintenance and Repairs	0.02	0.1	0.06	R 1 376 484.15
Operating Supplies	0.1	0.2	0.15	R 206 472.62
Laboritory Charges	0.1	0.2	0.15	R 427 080.60
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 5 861 434.43
Depreciation			0.1	R 2 294 140.24
Local Taxes and Insurance	0.014	0.05	0.032	R 734 124.88
Plant Overhead Costs	0.5	0.7	0.6	R 2 833 169.31
General Expences -GE				R 3 579 678.96
Administration			0.15	R 708 292.33
Distribution and Selling	0.02	0.2	0.11	R 1 974 078.31
Research and Development			0.05	R 897 308.32
Cost of Manufacturing - COM				R 17 946 166.43
Cost of Manufacturing without depreciation - COM_d				R 15 652 026.19
Income				R 13 283 362.07

Figure C-5: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 10 000 ton Charcoal scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 15 865 602.09
Purchased-equipment installation	0.45	0.39	0.47	R 6 187 584.82
Controls and instrumentation	0.09	0.13	0.18	R 2 062 528.27
Piping	0.16	0.31	0.66	R 4 918 336.65
Electrical	0.1	0.1	0.11	R 1 586 560.21
Buildings	0.25	0.29	0.18	R 4 601 024.61
Yard improvements	0.13	0.1	0.1	R 1 586 560.21
Service facilities	0.4	0.55	0.7	R 8 726 081.15
Land (if it must be purchased)	0.06	0.06	0.06	
				R 45 534 278.01
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 5 076 992.67
Construction expenses	0.39	0.34	0.41	R 5 394 304.71
Contractors fee	0.17	0.18	0.21	R 2 855 808.38
Contingency	0.34	0.36	0.42	R 5 711 616.75
				R 19 038 722.51
FCI				R 64 573 000.53
Initial Loan Amount - P				R 64 573 000.53
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 183 686 269.84
Payment Amount per period - A				R 871 315.76
Total Annual amount				R 10 455 789.14
Depreciation				R 6 457 300.05
Fixed Capital Investment				R 64 573 000.53
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 28 071 542.85
Raw Materials				R 13 750 000.00
Waste Treatment				R 0.00
Utilities				R 664 675.82
Operating Labour				R 6 944 400.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 1 215 270.00
Maintenance and Repairs	0.02	0.1	0.06	R 3 874 380.03
Operating Supplies	0.1	0.2	0.15	R 581 157.00
Laboritory Charges	0.1	0.2	0.15	R 1 041 660.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 15 744 066.09
Depreciation			0.1	R 6 457 300.05
Local Taxes and Insurance	0.014	0.05	0.032	R 2 066 336.02
Plant Overhead Costs	0.5	0.7	0.6	R 7 220 430.02
General Expences -GE				R 10 568 100.05
Administration			0.15	R 1 805 107.50
Distribution and Selling	0.02	0.2	0.11	R 6 024 557.37
Research and Development			0.05	R 2 738 435.17
Cost of Manufacturing - COM				R 54 768 703.40
Cost of Manufacturing without depreciation - COM_d				R 48 311 403.35
Income				R 66 419 216.84

Figure C-6: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 50 000 ton Charcoal scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 24 047 798.89
Purchased-equipment installation	0.45	0.39	0.47	R 9 378 641.57
Controls and instrumentation	0.09	0.13	0.18	R 3 126 213.86
Piping	0.16	0.31	0.66	R 7 454 817.66
Electrical	0.1	0.1	0.11	R 2 404 779.89
Buildings	0.25	0.29	0.18	R 6 973 861.68
Yard improvements	0.13	0.1	0.1	R 2 404 779.89
Service facilities	0.4	0.55	0.7	R 13 226 289.39
Land (if it must be purchased)	0.06	0.06	0.06	
				R 69 017 182.81
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 7 695 295.64
Construction expenses	0.39	0.34	0.41	R 8 176 251.62
Contractors fee	0.17	0.18	0.21	R 4 328 603.80
Contingency	0.34	0.36	0.42	R 8 657 207.60
				R 28 857 358.67
FCI				R 97 874 541.48
Initial Loan Amount - P				R 97 874 541.48
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 278 416 819.58
Payment Amount per period - A				R 1 320 670.09
Total Annual amount				R 15 848 041.13
Depreciation				R 9 787 454.15
Fixed Capital Investment				R 97 874 541.48
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 49 047 150.24
Raw Materials				R 27 500 000.00
Waste Treatment				R 0.00
Utilities				R 991 811.88
Operating Labour				R 10 416 600.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 1 822 905.00
Maintenance and Repairs	0.02	0.1	0.06	R 5 872 472.49
Operating Supplies	0.1	0.2	0.15	R 880 870.87
Laboritory Charges	0.1	0.2	0.15	R 1 562 490.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 23 786 625.97
Depreciation			0.1	R 9 787 454.15
Local Taxes and Insurance	0.014	0.05	0.032	R 3 131 985.33
Plant Overhead Costs	0.5	0.7	0.6	R 10 867 186.49
General Expences -GE				R 17 258 735.54
Administration			0.15	R 2 716 796.62
Distribution and Selling	0.02	0.2	0.11	R 9 997 583.00
Research and Development			0.05	R 4 544 355.91
Cost of Manufacturing - COM				R 90 887 118.23
Cost of Manufacturing without depreciation - COM_d				R 81 099 664.08
Income				R 132 838 433.67

Figure C-7: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 100 000 ton Charcoal scenario.

Capital Investment				
Direct Costs	**Solid-processing**	**Solid-Fluid proces**	**Fluid-processing**	**Cost**
Purchased equipment-delivered	1	1	1	R 642 810.14
Purchased-equipment installation	0.45	0.39	0.47	R 250 695.95
Controls and instrumentation	0.09	0.13	0.18	R 83 565.32
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 64 281.01
Buildings	0.25	0.29	0.18	R 186 414.94
Yard improvements	0.13	0.1	0.1	R 64 281.01
Service facilities	0.4	0.55	0.7	R 353 545.57
Land (if it must be purchased)	0.06	0.06	0.06	
				R 1 645 593.95
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 205 699.24
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 115 705.82
Contingency	0.34	0.36	0.42	R 231 411.65
				R 552 816.72
FCI				R 2 198 410.66
Initial Loan Amount - P				R 2 198 410.66
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 6 253 664.09
Payment Amount per period - A				R 29 664.25
Total Annual amount				R 355 971.04
Depreciation				R 219 841.07
Fixed Capital Investment				R 2 198 410.66
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 1 311 004.36
Raw Materials				R 137 500.00
Waste Treatment				R 0.00
Utilities				R 40 338.83
Operating Labour				R 740 736.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 129 628.80
Maintenance and Repairs	0.02	0.1	0.06	R 131 904.64
Operating Supplies	0.1	0.2	0.15	R 19 785.70
Laboritory Charges	0.1	0.2	0.15	R 111 110.40
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 891 551.87
Depreciation			0.1	R 219 841.07
Local Taxes and Insurance	0.014	0.05	0.032	R 70 349.14
Plant Overhead Costs	0.5	0.7	0.6	R 601 361.66
General Expences -GE				R 464 556.08
Administration			0.15	R 150 340.42
Distribution and Selling	0.02	0.2	0.11	R 314 215.66
Research and Development			0.05	
Cost of Manufacturing - COM				R 2 856 506.03
Cost of Manufacturing without depreciation - COM_d				R 2 636 664.96
Income				R 376 363.64

Figure C-8: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 500 ton Biochar scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 642 810.14
Purchased-equipment installation	0.45	0.39	0.47	R 250 695.95
Controls and instrumentation	0.09	0.13	0.18	R 83 565.32
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 64 281.01
Buildings	0.25	0.29	0.18	R 186 414.94
Yard improvements	0.13	0.1	0.1	R 64 281.01
Service facilities	0.4	0.55	0.7	R 353 545.57
Land (if it must be purchased)	0.06	0.06	0.06	
				R 1 645 593.95
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 205 699.24
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 115 705.82
Contingency	0.34	0.36	0.42	R 231 411.65
				R 552 816.72
FCI				R 2 198 410.66
Initial Loan Amount - P				R 2 198 410.66
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 6 253 664.09
Payment Amount per period - A				R 29 664.25
Total Annual amount				R 355 971.04
Depreciation				R 219 841.07
Fixed Capital Investment				R 2 198 410.66
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 1 448 504.36
Raw Materials				R 275 000.00
Waste Treatment				R 0.00
Utilities				R 40 338.83
Operating Labour				R 740 736.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 129 628.80
Maintenance and Repairs	0.02	0.1	0.06	R 131 904.64
Operating Supplies	0.1	0.2	0.15	R 19 785.70
Laboritory Charges	0.1	0.2	0.15	R 111 110.40
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 891 551.87
Depreciation			0.1	R 219 841.07
Local Taxes and Insurance	0.014	0.05	0.032	R 70 349.14
Plant Overhead Costs	0.5	0.7	0.6	R 601 361.66
General Expences -GE				R 483 159.83
Administration			0.15	R 150 340.42
Distribution and Selling	0.02	0.2	0.11	R 332 819.41
Research and Development			0.05	
Cost of Manufacturing - COM				R 3 025 631.03
Cost of Manufacturing without depreciation - COM_d				R 2 805 789.96
Income				R 752 727.27

Figure C-9: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 1000 ton Biochar scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 642 810.14
Purchased-equipment installation	0.45	0.39	0.47	R 250 695.95
Controls and instrumentation	0.09	0.13	0.18	R 83 565.32
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 64 281.01
Buildings	0.25	0.29	0.18	R 186 414.94
Yard improvements	0.13	0.1	0.1	R 64 281.01
Service facilities	0.4	0.55	0.7	R 353 545.57
Land (if it must be purchased)	0.06	0.06	0.06	
				R 1 645 593.95
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 205 699.24
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 115 705.82
Contingency	0.34	0.36	0.42	R 231 411.65
				R 552 816.72
FCI				R 2 198 410.66
Initial Loan Amount - P				R 2 198 410.66
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 6 253 664.09
Payment Amount per period - A				R 29 664.25
Total Annual amount				R 355 971.04
Depreciation				R 219 841.07
Fixed Capital Investment				R 2 198 410.66
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 2 361 734.69
Raw Materials				R 687 500.00
Waste Treatment				R 0.00
Utilities				R 50 331.56
Operating Labour				R 1 111 104.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 194 443.20
Maintenance and Repairs	0.02	0.1	0.06	R 131 904.64
Operating Supplies	0.1	0.2	0.15	R 19 785.70
Laboritory Charges	0.1	0.2	0.15	R 166 665.60
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 1 152 661.31
Depreciation			0.1	R 219 841.07
Local Taxes and Insurance	0.014	0.05	0.032	R 70 349.14
Plant Overhead Costs	0.5	0.7	0.6	R 862 471.10
General Expences -GE				R 944 642.05
Administration			0.15	R 215 617.78
Distribution and Selling	0.02	0.2	0.11	R 501 204.19
Research and Development			0.05	R 227 820.09
Cost of Manufacturing - COM				R 4 556 401.72
Cost of Manufacturing without depreciation - COM_d				R 4 336 560.65
Income				R 1 881 818.18

Figure C-10: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 2500 ton Biochar scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 642 810.14
Purchased-equipment installation	0.45	0.39	0.47	R 250 695.95
Controls and instrumentation	0.09	0.13	0.18	R 83 565.32
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 64 281.01
Buildings	0.25	0.29	0.18	R 186 414.94
Yard improvements	0.13	0.1	0.1	R 64 281.01
Service facilities	0.4	0.55	0.7	R 353 545.57
Land (if it must be purchased)	0.06	0.06	0.06	
				R 1 645 593.95
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 205 699.24
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 115 705.82
Contingency	0.34	0.36	0.42	R 231 411.65
				R 552 816.72
FCI				R 2 198 410.66
Initial Loan Amount - P				R 2 198 410.66
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 6 253 664.09
Payment Amount per period - A				R 29 664.25
Total Annual amount				R 355 971.04
Depreciation				R 219 841.07
Fixed Capital Investment				R 2 198 410.66
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 3 549 965.02
Raw Materials				R 1 375 000.00
Waste Treatment				R 0.00
Utilities				R 60 324.29
Operating Labour				R 1 481 472.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 259 257.60
Maintenance and Repairs	0.02	0.1	0.06	R 131 904.64
Operating Supplies	0.1	0.2	0.15	R 19 785.70
Laboritory Charges	0.1	0.2	0.15	R 222 220.80
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 1 413 770.75
Depreciation			0.1	R 219 841.07
Local Taxes and Insurance	0.014	0.05	0.032	R 70 349.14
Plant Overhead Costs	0.5	0.7	0.6	R 1 123 580.54
General Expences -GE				R 1 308 962.72
Administration			0.15	R 280 895.14
Distribution and Selling	0.02	0.2	0.11	R 706 796.47
Research and Development			0.05	R 321 271.12
Cost of Manufacturing - COM				R 6 425 422.42
Cost of Manufacturing without depreciation - COM_d				R 6 205 581.35
Income				R 3 763 636.36

Figure C-11: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 5000 ton Biochar scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 1 223 811.33
Purchased-equipment installation	0.45	0.39	0.47	R 477 286.42
Controls and instrumentation	0.09	0.13	0.18	R 159 095.47
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 122 381.13
Buildings	0.25	0.29	0.18	R 354 905.29
Yard improvements	0.13	0.1	0.1	R 122 381.13
Service facilities	0.4	0.55	0.7	R 673 096.23
Land (if it must be purchased)	0.06	0.06	0.06	
				R 3 132 957.01
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 391 619.63
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 220 286.04
Contingency	0.34	0.36	0.42	R 440 572.08
				R 1 052 477.74
FCI				R 4 185 434.75
Initial Loan Amount - P				R 4 185 434.75
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 11 906 011.66
Payment Amount per period - A				R 56 476.16
Total Annual amount				R 677 713.95
Depreciation				R 418 543.48
Fixed Capital Investment				R 4 185 434.75
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 5 096 712.79
Raw Materials				R 2 750 000.00
Waste Treatment				R 0.00
Utilities				R 94 967.40
Operating Labour				R 1 481 472.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 259 257.60
Maintenance and Repairs	0.02	0.1	0.06	R 251 126.09
Operating Supplies	0.1	0.2	0.15	R 37 668.91
Laboritory Charges	0.1	0.2	0.15	R 222 220.80
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 1 747 590.80
Depreciation			0.1	R 418 543.48
Local Taxes and Insurance	0.014	0.05	0.032	R 133 933.91
Plant Overhead Costs	0.5	0.7	0.6	R 1 195 113.41
General Expences -GE				R 1 693 282.38
Administration			0.15	R 298 778.35
Distribution and Selling	0.02	0.2	0.11	R 958 721.52
Research and Development			0.05	R 435 782.51
Cost of Manufacturing - COM				R 8 715 650.19
Cost of Manufacturing without depreciation - COM_d				R 8 297 106.71
Income				R 7 527 272.73

Figure C-12: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 10 000 ton Biochar scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 2 912 036.66
Purchased-equipment installation	0.45	0.39	0.47	R 1 135 694.30
Controls and instrumentation	0.09	0.13	0.18	R 378 564.77
Piping	0.16	0.31	0.66	R 902 731.36
Electrical	0.1	0.1	0.11	R 291 203.67
Buildings	0.25	0.29	0.18	R 844 490.63
Yard improvements	0.13	0.1	0.1	R 291 203.67
Service facilities	0.4	0.55	0.7	R 1 601 620.16
Land (if it must be purchased)	0.06	0.06	0.06	
				R 8 357 545.21
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 931 851.73
Construction expenses	0.39	0.34	0.41	R 990 092.46
Contractors fee	0.17	0.18	0.21	R 524 166.60
Contingency	0.34	0.36	0.42	R 1 048 333.20
				R 3 494 443.99
FCI				R 11 851 989.20
Initial Loan Amount - P				R 11 851 989.20
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 33 714 519.52
Payment Amount per period - A				R 159 924.81
Total Annual amount				R 1 919 097.75
Depreciation				R 1 185 198.92
Fixed Capital Investment				R 11 851 989.20
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 19 659 274.55
Raw Materials				R 13 750 000.00
Waste Treatment				R 0.00
Utilities				R 184 111.29
Operating Labour				R 3 703 680.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 648 144.00
Maintenance and Repairs	0.02	0.1	0.06	R 711 119.35
Operating Supplies	0.1	0.2	0.15	R 106 667.90
Laboritory Charges	0.1	0.2	0.15	R 555 552.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 4 602 228.59
Depreciation			0.1	R 1 185 198.92
Local Taxes and Insurance	0.014	0.05	0.032	R 379 263.65
Plant Overhead Costs	0.5	0.7	0.6	R 3 037 766.01
General Expences -GE				R 5 650 411.15
Administration			0.15	R 759 441.50
Distribution and Selling	0.02	0.2	0.11	R 3 362 541.63
Research and Development			0.05	R 1 528 428.01
Cost of Manufacturing - COM				R 30 568 560.27
Cost of Manufacturing without depreciation - COM_d				R 29 383 361.35
Income				R 37 636 363.64

Figure C-13: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 50 000 ton Biochar scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 4 924 062.00
Purchased-equipment installation	0.45	0.39	0.47	R 1 920 384.18
Controls and instrumentation	0.09	0.13	0.18	R 640 128.06
Piping	0.16	0.31	0.66	R 1 526 459.22
Electrical	0.1	0.1	0.11	R 492 406.20
Buildings	0.25	0.29	0.18	R 1 427 977.98
Yard improvements	0.13	0.1	0.1	R 492 406.20
Service facilities	0.4	0.55	0.7	R 2 708 234.10
Land (if it must be purchased)	0.06	0.06	0.06	
				R 14 132 057.94
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 1 575 699.84
Construction expenses	0.39	0.34	0.41	R 1 674 181.08
Contractors fee	0.17	0.18	0.21	R 886 331.16
Contingency	0.34	0.36	0.42	R 1 772 662.32
				R 5 908 874.40
FCI				R 20 040 932.34
Initial Loan Amount - P				R 20 040 932.34
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 57 009 029.71
Payment Amount per period - A				R 270 422.31
Total Annual amount				R 3 245 067.77
Depreciation				R 2 004 093.23
Fixed Capital Investment				R 20 040 932.34
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 36 507 298.88
Raw Materials				R 27 500 000.00
Waste Treatment				R 0.00
Utilities				R 263 410.55
Operating Labour				R 5 555 520.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 972 216.00
Maintenance and Repairs	0.02	0.1	0.06	R 1 202 455.94
Operating Supplies	0.1	0.2	0.15	R 180 368.39
Laboritory Charges	0.1	0.2	0.15	R 833 328.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 7 283 518.23
Depreciation			0.1	R 2 004 093.23
Local Taxes and Insurance	0.014	0.05	0.032	R 641 309.83
Plant Overhead Costs	0.5	0.7	0.6	R 4 638 115.16
General Expences -GE				R 9 947 852.89
Administration			0.15	R 1 159 528.79
Distribution and Selling	0.02	0.2	0.11	R 6 041 972.82
Research and Development			0.05	R 2 746 351.28
Cost of Manufacturing - COM				R 54 927 025.63
Cost of Manufacturing without depreciation - COM_d				R 52 922 932.40
Income				R 75 272 727.27

Figure C-14: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 100 000 ton Biochar scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 8 333 791.63
Purchased-equipment installation	0.45	0.39	0.47	R 3 250 178.74
Controls and instrumentation	0.09	0.13	0.18	R 1 083 392.91
Piping	0.16	0.31	0.66	R 2 583 475.41
Electrical	0.1	0.1	0.11	R 833 379.16
Buildings	0.25	0.29	0.18	R 2 416 799.57
Yard improvements	0.13	0.1	0.1	R 833 379.16
Service facilities	0.4	0.55	0.7	R 4 583 585.40
Land (if it must be purchased)	0.06	0.06	0.06	
				R 23 917 981.99
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 2 666 813.32
Construction expenses	0.39	0.34	0.41	R 2 833 489.16
Contractors fee	0.17	0.18	0.21	R 1 500 082.49
Contingency	0.34	0.36	0.42	R 3 000 164.99
				R 10 000 549.96
FCI				R 33 918 531.95
Initial Loan Amount - P				R 33 918 531.95
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 96 485 660.61
Payment Amount per period - A				R 457 679.70
Total Annual amount				R 5 492 156.40
Depreciation				R 3 391 853.20
Fixed Capital Investment				R 33 918 531.95
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 5 823 415.99
Raw Materials				R 376 363.64
Waste Treatment				R 24 313.09
Utilities				R 751 356.96
Operating Labour				R 1 759 248.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 307 868.40
Maintenance and Repairs	0.02	0.1	0.06	R 2 035 111.92
Operating Supplies	0.1	0.2	0.15	R 305 266.79
Laboritory Charges	0.1	0.2	0.15	R 263 887.20
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 6 938 583.21
Depreciation			0.1	R 3 391 853.20
Local Taxes and Insurance	0.014	0.05	0.032	R 1 085 393.02
Plant Overhead Costs	0.5	0.7	0.6	R 2 461 336.99
General Expences -GE				R 2 344 197.36
Administration			0.15	R 615 334.25
Distribution and Selling	0.02	0.2	0.11	R 1 728 863.12
Research and Development			0.05	
Cost of Manufacturing - COM				R 15 716 937.42
Cost of Manufacturing without depreciation - COM_d				R 12 325 084.22
Income				R 1 695 536.49

Figure C-15: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 500 ton Activated Carbon scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 8 333 791.63
Purchased-equipment installation	0.45	0.39	0.47	R 3 250 178.74
Controls and instrumentation	0.09	0.13	0.18	R 1 083 392.91
Piping	0.16	0.31	0.66	R 2 583 475.41
Electrical	0.1	0.1	0.11	R 833 379.16
Buildings	0.25	0.29	0.18	R 2 416 799.57
Yard improvements	0.13	0.1	0.1	R 833 379.16
Service facilities	0.4	0.55	0.7	R 4 583 585.40
Land (if it must be purchased)	0.06	0.06	0.06	
				R 23 917 981.99
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 2 666 813.32
Construction expenses	0.39	0.34	0.41	R 2 833 489.16
Contractors fee	0.17	0.18	0.21	R 1 500 082.49
Contingency	0.34	0.36	0.42	R 3 000 164.99
				R 10 000 549.96
FCI				R 33 918 531.95
Initial Loan Amount - P				R 33 918 531.95
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 96 485 660.61
Payment Amount per period - A				R 457 679.70
Total Annual amount				R 5 492 156.40
Depreciation				R 3 391 853.20
Fixed Capital Investment				R 33 918 531.95
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 6 232 664.78
Raw Materials				R 752 727.27
Waste Treatment				R 48 626.18
Utilities				R 759 929.02
Operating Labour				R 1 759 248.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 307 868.40
Maintenance and Repairs	0.02	0.1	0.06	R 2 035 111.92
Operating Supplies	0.1	0.2	0.15	R 305 266.79
Laboritory Charges	0.1	0.2	0.15	R 263 887.20
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 6 938 583.21
Depreciation			0.1	R 3 391 853.20
Local Taxes and Insurance	0.014	0.05	0.032	R 1 085 393.02
Plant Overhead Costs	0.5	0.7	0.6	R 2 461 336.99
General Expences -GE				R 2 399 568.72
Administration			0.15	R 615 334.25
Distribution and Selling	0.02	0.2	0.11	R 1 784 234.48
Research and Development			0.05	
Cost of Manufacturing - COM				R 16 220 313.43
Cost of Manufacturing without depreciation - COM_d				R 12 828 460.23
Income				R 3 391 072.98

Figure C-16: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 1000 ton Activated Carbon scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 8 333 791.63
Purchased-equipment installation	0.45	0.39	0.47	R 3 250 178.74
Controls and instrumentation	0.09	0.13	0.18	R 1 083 392.91
Piping	0.16	0.31	0.66	R 2 583 475.41
Electrical	0.1	0.1	0.11	R 833 379.16
Buildings	0.25	0.29	0.18	R 2 416 799.57
Yard improvements	0.13	0.1	0.1	R 833 379.16
Service facilities	0.4	0.55	0.7	R 4 583 585.40
Land (if it must be purchased)	0.06	0.06	0.06	
				R 23 917 981.99
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 2 666 813.32
Construction expenses	0.39	0.34	0.41	R 2 833 489.16
Contractors fee	0.17	0.18	0.21	R 1 500 082.49
Contingency	0.34	0.36	0.42	R 3 000 164.99
				R 10 000 549.96
FCI				R 33 918 531.95
Initial Loan Amount - P				R 33 918 531.95
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 96 485 660.61
Payment Amount per period - A				R 457 679.70
Total Annual amount				R 5 492 156.40
Depreciation				R 3 391 853.20
Fixed Capital Investment				R 33 918 531.95
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 7 460 411.13
Raw Materials				R 1 881 818.18
Waste Treatment				R 121 565.45
Utilities				R 785 645.19
Operating Labour				R 1 759 248.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 307 868.40
Maintenance and Repairs	0.02	0.1	0.06	R 2 035 111.92
Operating Supplies	0.1	0.2	0.15	R 305 266.79
Laboritory Charges	0.1	0.2	0.15	R 263 887.20
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 6 938 583.21
Depreciation			0.1	R 3 391 853.20
Local Taxes and Insurance	0.014	0.05	0.032	R 1 085 393.02
Plant Overhead Costs	0.5	0.7	0.6	R 2 461 336.99
General Expences -GE				R 3 452 204.88
Administration			0.15	R 615 334.25
Distribution and Selling	0.02	0.2	0.11	R 1 950 348.56
Research and Development			0.05	R 886 522.07
Cost of Manufacturing - COM				R 17 730 441.44
Cost of Manufacturing without depreciation - COM_d				R 14 338 588.25
Income				R 8 477 682.44

Figure C-17: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 2500 ton Activated Carbon scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 8 333 791.63
Purchased-equipment installation	0.45	0.39	0.47	R 3 250 178.74
Controls and instrumentation	0.09	0.13	0.18	R 1 083 392.91
Piping	0.16	0.31	0.66	R 2 583 475.41
Electrical	0.1	0.1	0.11	R 833 379.16
Buildings	0.25	0.29	0.18	R 2 416 799.57
Yard improvements	0.13	0.1	0.1	R 833 379.16
Service facilities	0.4	0.55	0.7	R 4 583 585.40
Land (if it must be purchased)	0.06	0.06	0.06	
				R 23 917 981.99
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 2 666 813.32
Construction expenses	0.39	0.34	0.41	R 2 833 489.16
Contractors fee	0.17	0.18	0.21	R 1 500 082.49
Contingency	0.34	0.36	0.42	R 3 000 164.99
				R 10 000 549.96
FCI				R 33 918 531.95
Initial Loan Amount - P				R 33 918 531.95
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 96 485 660.61
Payment Amount per period - A				R 457 679.70
Total Annual amount				R 5 492 156.40
Depreciation				R 3 391 853.20
Fixed Capital Investment				R 33 918 531.95
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 9 506 655.06
Raw Materials				R 3 763 636.36
Waste Treatment				R 243 130.91
Utilities				R 828 505.48
Operating Labour				R 1 759 248.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 307 868.40
Maintenance and Repairs	0.02	0.1	0.06	R 2 035 111.92
Operating Supplies	0.1	0.2	0.15	R 305 266.79
Laboritory Charges	0.1	0.2	0.15	R 263 887.20
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 6 938 583.21
Depreciation			0.1	R 3 391 853.20
Local Taxes and Insurance	0.014	0.05	0.032	R 1 085 393.02
Plant Overhead Costs	0.5	0.7	0.6	R 2 461 336.99
General Expences -GE				R 3 854 905.68
Administration			0.15	R 615 334.25
Distribution and Selling	0.02	0.2	0.11	R 2 227 205.36
Research and Development			0.05	R 1 012 366.07
Cost of Manufacturing - COM				R 20 247 321.48
Cost of Manufacturing without depreciation - COM_d				R 16 855 468.28
Income				R 16 955 364.88

Figure C-18: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 5000 ton Activated Carbon scenario

Capital Investment	Equipment cost ZAR	0	Product cost ZAR	0
Direct Costs	**Solid-processing**	**Solid-Fluid proces**	**Fluid-processing**	**Cost**
Purchased equipment-delivered	1	1	1	R 8 633 734.80
Purchased-equipment installation	0.45	0.39	0.47	R 3 367 156.57
Controls and instrumentation	0.09	0.13	0.18	R 1 122 385.52
Piping	0.16	0.31	0.66	R 2 676 457.79
Electrical	0.1	0.1	0.11	R 863 373.48
Buildings	0.25	0.29	0.18	R 2 503 783.09
Yard improvements	0.13	0.1	0.1	R 863 373.48
Service facilities	0.4	0.55	0.7	R 4 748 554.14
Land (if it must be purchased)	0.06	0.06	0.06	
				R 24 778 818.88
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 2 762 795.14
Construction expenses	0.39	0.34	0.41	R 2 935 469.83
Contractors fee	0.17	0.18	0.21	R 1 554 072.26
Contingency	0.34	0.36	0.42	R 3 108 144.53
				R 10 360 481.76
FCI				R 35 139 300.65
Initial Loan Amount - P				R 35 139 300.65
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 99 958 295.39
Payment Amount per period - A				R 474 152.14
Total Annual amount				R 5 689 825.70
Depreciation				R 3 513 930.06
Fixed Capital Investment				R 35 139 300.65
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 14 199 755.08
Raw Materials				R 7 527 272.73
Waste Treatment				R 486 261.82
Utilities				R 939 867.59
Operating Labour				R 2 129 616.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 372 682.80
Maintenance and Repairs	0.02	0.1	0.06	R 2 108 358.04
Operating Supplies	0.1	0.2	0.15	R 316 253.71
Laboritory Charges	0.1	0.2	0.15	R 319 442.40
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 7 404 781.79
Depreciation			0.1	R 3 513 930.06
Local Taxes and Insurance	0.014	0.05	0.032	R 1 124 457.62
Plant Overhead Costs	0.5	0.7	0.6	R 2 766 394.10
General Expences -GE				R 4 958 085.00
Administration			0.15	R 691 598.53
Distribution and Selling	0.02	0.2	0.11	R 2 933 209.45
Research and Development			0.05	R 1 333 277.02
Cost of Manufacturing - COM				R 26 665 540.49
Cost of Manufacturing without depreciation - COM_d				R 23 151 610.42
Income				R 33 910 729.76

Figure C-19: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 10 000 ton Activated Carbon scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 22 676 744.51
Purchased-equipment installation	0.45	0.39	0.47	R 8 843 930.36
Controls and instrumentation	0.09	0.13	0.18	R 2 947 976.79
Piping	0.16	0.31	0.66	R 7 029 790.80
Electrical	0.1	0.1	0.11	R 2 267 674.45
Buildings	0.25	0.29	0.18	R 6 576 255.91
Yard improvements	0.13	0.1	0.1	R 2 267 674.45
Service facilities	0.4	0.55	0.7	R 12 472 209.48
Land (if it must be purchased)	0.06	0.06	0.06	
				R 65 082 256.76
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 7 256 558.24
Construction expenses	0.39	0.34	0.41	R 7 710 093.13
Contractors fee	0.17	0.18	0.21	R 4 081 814.01
Contingency	0.34	0.36	0.42	R 8 163 628.03
				R 27 212 093.42
FCI				R 92 294 350.17
Initial Loan Amount - P				R 92 294 350.17
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 262 543 242.11
Payment Amount per period - A				R 1 245 373.78
Total Annual amount				R 14 944 485.41
Depreciation				R 9 229 435.02
Fixed Capital Investment				R 92 294 350.17
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 56 009 765.31
Raw Materials				R 37 636 363.64
Waste Treatment				R 2 431 309.09
Utilities				R 2 826 140.42
Operating Labour				R 5 092 560.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 891 198.00
Maintenance and Repairs	0.02	0.1	0.06	R 5 537 661.01
Operating Supplies	0.1	0.2	0.15	R 830 649.15
Laboritory Charges	0.1	0.2	0.15	R 763 884.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 19 095 705.63
Depreciation			0.1	R 9 229 435.02
Local Taxes and Insurance	0.014	0.05	0.032	R 2 953 419.21
Plant Overhead Costs	0.5	0.7	0.6	R 6 912 851.41
General Expences -GE				R 16 528 932.37
Administration			0.15	R 1 728 212.85
Distribution and Selling	0.02	0.2	0.11	R 10 175 494.67
Research and Development			0.05	R 4 625 224.85
Cost of Manufacturing - COM				R 92 504 497.02
Cost of Manufacturing without depreciation - COM_d				R 83 275 062.00
Income				R 169 553 648.81

Figure C-20: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 50 000 ton Activated Carbon scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 34 371 517.33
Purchased-equipment installation	0.45	0.39	0.47	R 13 404 891.76
Controls and instrumentation	0.09	0.13	0.18	R 4 468 297.25
Piping	0.16	0.31	0.66	R 10 655 170.37
Electrical	0.1	0.1	0.11	R 3 437 151.73
Buildings	0.25	0.29	0.18	R 9 967 740.03
Yard improvements	0.13	0.1	0.1	R 3 437 151.73
Service facilities	0.4	0.55	0.7	R 18 904 334.53
Land (if it must be purchased)	0.06	0.06	0.06	
				R 98 646 254.75
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 10 998 885.55
Construction expenses	0.39	0.34	0.41	R 11 686 315.89
Contractors fee	0.17	0.18	0.21	R 6 186 873.12
Contingency	0.34	0.36	0.42	R 12 373 746.24
				R 41 245 820.80
FCI				R 139 892 075.55
Initial Loan Amount - P				R 139 892 075.55
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 397 941 141.50
Payment Amount per period - A				R 1 887 633.68
Total Annual amount				R 22 651 604.12
Depreciation				R 13 989 207.56
Fixed Capital Investment				R 139 892 075.55
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 104 408 443.51
Raw Materials				R 75 272 727.27
Waste Treatment				R 4 862 618.18
Utilities				R 4 683 108.45
Operating Labour				R 7 499 952.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 1 312 491.60
Maintenance and Repairs	0.02	0.1	0.06	R 8 393 524.53
Operating Supplies	0.1	0.2	0.15	R 1 259 028.68
Laboritory Charges	0.1	0.2	0.15	R 1 124 992.80
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 28 789 334.85
Depreciation			0.1	R 13 989 207.56
Local Taxes and Insurance	0.014	0.05	0.032	R 4 476 546.42
Plant Overhead Costs	0.5	0.7	0.6	R 10 323 580.88
General Expences -GE				R 28 816 310.97
Administration			0.15	R 2 580 895.22
Distribution and Selling	0.02	0.2	0.11	R 18 036 848.33
Research and Development			0.05	R 8 198 567.42
Cost of Manufacturing - COM				R 163 971 348.41
Cost of Manufacturing without depreciation - COM_d				R 149 982 140.86
Income				R 339 107 297.63

Figure C-21: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 100 000 ton Activated Carbon scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 5 487 751.20
Purchased-equipment installation	0.45	0.39	0.47	R 2 469 488.04
Controls and instrumentation	0.09	0.13	0.18	R 493 897.61
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 548 775.12
Buildings	0.25	0.29	0.18	R 1 371 937.80
Yard improvements	0.13	0.1	0.1	R 713 407.66
Service facilities	0.4	0.55	0.7	R 2 195 100.48
Land (if it must be purchased)	0.06	0.06	0.06	
				R 13 280 357.91
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 1 810 957.90
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 932 917.70
Contingency	0.34	0.36	0.42	R 1 865 835.41
				R 4 609 711.01
FCI				R 17 890 068.92
Initial Loan Amount - P				R 17 890 068.92
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 50 890 619.93
Payment Amount per period - A				R 241 399.64
Total Annual amount				R 2 896 795.67
Depreciation				R 1 789 006.89
Fixed Capital Investment				R 17 890 068.92
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 6 016 591.06
Raw Materials				R 137 500.00
Waste Treatment				R 0.00
Utilities				R 350 722.31
Operating Labour				R 3 240 720.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 567 126.00
Maintenance and Repairs	0.02	0.1	0.06	R 1 073 404.14
Operating Supplies	0.1	0.2	0.15	R 161 010.62
Laboritory Charges	0.1	0.2	0.15	R 486 108.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 5 290 239.18
Depreciation			0.1	R 1 789 006.89
Local Taxes and Insurance	0.014	0.05	0.032	R 572 482.21
Plant Overhead Costs	0.5	0.7	0.6	R 2 928 750.08
General Expences -GE				R 2 322 446.34
Administration			0.15	R 732 187.52
Distribution and Selling	0.02	0.2	0.11	R 1 590 258.82
Research and Development			0.05	
Cost of Manufacturing - COM				R 14 456 898.34
Cost of Manufacturing without depreciation - COM_d				R 12 667 891.44
Income				R 1 754 457.10

Figure C-22: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 500 ton Laminated Board scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 5 487 751.20
Purchased-equipment installation	0.45	0.39	0.47	R 2 469 488.04
Controls and instrumentation	0.09	0.13	0.18	R 493 897.61
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 548 775.12
Buildings	0.25	0.29	0.18	R 1 371 937.80
Yard improvements	0.13	0.1	0.1	R 713 407.66
Service facilities	0.4	0.55	0.7	R 2 195 100.48
Land (if it must be purchased)	0.06	0.06	0.06	
				R 13 280 357.91
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 1 810 957.90
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 932 917.70
Contingency	0.34	0.36	0.42	R 1 865 835.41
				R 4 609 711.01
FCI				R 17 890 068.92
Initial Loan Amount - P				R 17 890 068.92
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 50 890 619.93
Payment Amount per period - A				R 241 399.64
Total Annual amount				R 2 896 795.67
Depreciation				R 1 789 006.89
Fixed Capital Investment				R 17 890 068.92
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 6 154 091.06
Raw Materials				R 275 000.00
Waste Treatment				R 0.00
Utilities				R 350 722.31
Operating Labour				R 3 240 720.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 567 126.00
Maintenance and Repairs	0.02	0.1	0.06	R 1 073 404.14
Operating Supplies	0.1	0.2	0.15	R 161 010.62
Laboritory Charges	0.1	0.2	0.15	R 486 108.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 5 290 239.18
Depreciation			0.1	R 1 789 006.89
Local Taxes and Insurance	0.014	0.05	0.032	R 572 482.21
Plant Overhead Costs	0.5	0.7	0.6	R 2 928 750.08
General Expences -GE				R 2 341 050.09
Administration			0.15	R 732 187.52
Distribution and Selling	0.02	0.2	0.11	R 1 608 862.57
Research and Development			0.05	
Cost of Manufacturing - COM				R 14 626 023.34
Cost of Manufacturing without depreciation - COM_d				R 12 837 016.44
Income				R 3 508 914.19

Figure C-23: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 1000 ton Laminated Board scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces:	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 5 487 751.20
Purchased-equipment installation	0.45	0.39	0.47	R 2 469 488.04
Controls and instrumentation	0.09	0.13	0.18	R 493 897.61
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 548 775.12
Buildings	0.25	0.29	0.18	R 1 371 937.80
Yard improvements	0.13	0.1	0.1	R 713 407.66
Service facilities	0.4	0.55	0.7	R 2 195 100.48
Land (if it must be purchased)	0.06	0.06	0.06	
				R 13 280 357.91
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 1 810 957.90
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 932 917.70
Contingency	0.34	0.36	0.42	R 1 865 835.41
				R 4 609 711.01
FCI				R 17 890 068.92
Initial Loan Amount - P				R 17 890 068.92
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 50 890 619.93
Payment Amount per period - A				R 241 399.64
Total Annual amount				R 2 896 795.67
Depreciation				R 1 789 006.89
Fixed Capital Investment				R 17 890 068.92
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 6 566 591.06
Raw Materials				R 687 500.00
Waste Treatment				R 0.00
Utilities				R 350 722.31
Operating Labour				R 3 240 720.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 567 126.00
Maintenance and Repairs	0.02	0.1	0.06	R 1 073 404.14
Operating Supplies	0.1	0.2	0.15	R 161 010.62
Laboritory Charges	0.1	0.2	0.15	R 486 108.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 5 290 239.18
Depreciation			0.1	R 1 789 006.89
Local Taxes and Insurance	0.014	0.05	0.032	R 572 482.21
Plant Overhead Costs	0.5	0.7	0.6	R 2 928 750.08
General Expences -GE				R 3 153 531.25
Administration			0.15	R 732 187.52
Distribution and Selling	0.02	0.2	0.11	R 1 664 673.82
Research and Development			0.05	R 756 669.92
Cost of Manufacturing - COM				R 15 133 398.34
Cost of Manufacturing without depreciation - COM_d				R 13 344 391.44
Income				R 7 706 207.17

Figure C-24: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 2500 ton Laminated Board scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 5 487 751.20
Purchased-equipment installation	0.45	0.39	0.47	R 2 469 488.04
Controls and instrumentation	0.09	0.13	0.18	R 493 897.61
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 548 775.12
Buildings	0.25	0.29	0.18	R 1 371 937.80
Yard improvements	0.13	0.1	0.1	R 713 407.66
Service facilities	0.4	0.55	0.7	R 2 195 100.48
Land (if it must be purchased)	0.06	0.06	0.06	
				R 13 280 357.91
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 1 810 957.90
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 932 917.70
Contingency	0.34	0.36	0.42	R 1 865 835.41
				R 4 609 711.01
FCI				R 17 890 068.92
Initial Loan Amount - P				R 17 890 068.92
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 50 890 619.93
Payment Amount per period - A				R 241 399.64
Total Annual amount				R 2 896 795.67
Depreciation				R 1 789 006.89
Fixed Capital Investment				R 17 890 068.92
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 11 868 421.27
Raw Materials				R 1 375 000.00
Waste Treatment				R 0.00
Utilities				R 671 098.52
Operating Labour				R 6 481 440.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 1 134 252.00
Maintenance and Repairs	0.02	0.1	0.06	R 1 073 404.14
Operating Supplies	0.1	0.2	0.15	R 161 010.62
Laboritory Charges	0.1	0.2	0.15	R 972 216.00
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 7 574 946.78
Depreciation			0.1	R 1 789 006.89
Local Taxes and Insurance	0.014	0.05	0.032	R 572 482.21
Plant Overhead Costs	0.5	0.7	0.6	R 5 213 457.68
General Expences -GE				R 5 338 604.69
Administration			0.15	R 1 303 364.42
Distribution and Selling	0.02	0.2	0.11	R 2 774 227.68
Research and Development			0.05	R 1 261 012.58
Cost of Manufacturing - COM				R 25 220 251.67
Cost of Manufacturing without depreciation - COM_d				R 23 431 244.78
Income				R 17 544 570.97

Figure C-25: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 5000 ton Laminated Board scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces:	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 13 626 792.86
Purchased-equipment installation	0.45	0.39	0.47	R 6 132 056.79
Controls and instrumentation	0.09	0.13	0.18	R 1 226 411.36
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 1 362 679.29
Buildings	0.25	0.29	0.18	R 3 406 698.21
Yard improvements	0.13	0.1	0.1	R 1 771 483.07
Service facilities	0.4	0.55	0.7	R 5 450 717.14
Land (if it must be purchased)	0.06	0.06	0.06	
				R 32 976 838.72
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 4 496 841.64
Construction expenses	0.39	0.34	0.41	
Contractors fee	0.17	0.18	0.21	R 2 316 554.79
Contingency	0.34	0.36	0.42	R 4 633 109.57
				R 11 446 506.00
FCI				R 44 423 344.72
Initial Loan Amount - P				R 44 423 344.72
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 126 367 962.14
Payment Amount per period - A				R 599 426.39
Total Annual amount				R 7 193 116.65
Depreciation				R 4 442 334.47
Fixed Capital Investment				R 44 423 344.72
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 17 314 635.06
Raw Materials				R 2 750 000.00
Waste Treatment				R 0.00
Utilities				R 825 881.48
Operating Labour				R 8 055 504.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 1 409 713.20
Maintenance and Repairs	0.02	0.1	0.06	R 2 665 400.68
Operating Supplies	0.1	0.2	0.15	R 399 810.10
Laboritory Charges	0.1	0.2	0.15	R 1 208 325.60
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 13 142 252.23
Depreciation			0.1	R 4 442 334.47
Local Taxes and Insurance	0.014	0.05	0.032	R 1 421 547.03
Plant Overhead Costs	0.5	0.7	0.6	R 7 278 370.73
General Expences -GE				R 8 032 136.15
Administration			0.15	R 1 819 592.68
Distribution and Selling	0.02	0.2	0.11	R 4 271 123.63
Research and Development			0.05	R 1 941 419.83
Cost of Manufacturing - COM				R 38 828 396.66
Cost of Manufacturing without depreciation - COM_d				R 34 386 062.19
Income				R 35 089 141.93

Figure C-26: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 10 000 ton Laminated Board scenario.

Capital Investment				
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 35 791 150.33
Purchased-equipment installation	0.45	0.39	0.47	R 16 106 017.65
Controls and instrumentation	0.09	0.13	0.18	R 3 221 203.53
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 3 579 115.03
Buildings	0.25	0.29	0.18	R 8 947 787.58
Yard improvements	0.13	0.1	0.1	R 4 652 849.54
Service facilities	0.4	0.55	0.7	R 14 316 460.13
Land (if it must be purchased)	0.06	0.06	0.06	
				R 86 614 583.80
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 11 811 079.61
Construction expenses	0.39	0.34	0.41	R 13 958 548.63
Contractors fee	0.17	0.18	0.21	R 6 084 495.56
Contingency	0.34	0.36	0.42	R 12 168 991.11
				R 44 023 114.91
FCI				R 130 637 698.71
Initial Loan Amount - P				R 130 637 698.71
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 371 615 867.02
Payment Amount per period - A				R 1 762 759.75
Total Annual amount				R 21 153 116.94
Depreciation				R 13 063 769.87
Fixed Capital Investment				R 130 637 698.71
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 52 978 570.70
Raw Materials				R 13 750 000.00
Waste Treatment				R 0.00
Utilities				R 2 119 841.89
Operating Labour				R 21 203 568.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 3 710 624.40
Maintenance and Repairs	0.02	0.1	0.06	R 7 838 261.92
Operating Supplies	0.1	0.2	0.15	R 1 175 739.29
Laboritory Charges	0.1	0.2	0.15	R 3 180 535.20
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 36 895 648.82
Depreciation			0.1	R 13 063 769.87
Local Taxes and Insurance	0.014	0.05	0.032	R 4 180 406.36
Plant Overhead Costs	0.5	0.7	0.6	R 19 651 472.59
General Expences -GE				R 23 150 340.44
Administration			0.15	R 4 912 868.15
Distribution and Selling	0.02	0.2	0.11	R 12 538 262.20
Research and Development			0.05	R 5 699 210.09
Cost of Manufacturing - COM				R 113 984 201.80
Cost of Manufacturing without depreciation - COM_d				R 100 920 431.93
Income				R 147 195 235.71

Figure C-27: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 50 000 ton Laminated Board scenario.

Capital Investment	Equipment cost ZAR			
Direct Costs	Solid-processing	Solid-Fluid proces	Fluid-processing	Cost
Purchased equipment-delivered	1	1	1	R 54 249 239.49
Purchased-equipment installation	0.45	0.39	0.47	R 24 412 157.77
Controls and instrumentation	0.09	0.13	0.18	R 4 882 431.55
Piping	0.16	0.31	0.66	
Electrical	0.1	0.1	0.11	R 5 424 923.95
Buildings	0.25	0.29	0.18	R 13 562 309.87
Yard improvements	0.13	0.1	0.1	R 7 052 401.13
Service facilities	0.4	0.55	0.7	R 21 699 695.80
Land (if it must be purchased)	0.06	0.06	0.06	
				R 131 283 159.57
Indirect Costs				
Engineering and supervision	0.33	0.32	0.33	R 17 902 249.03
Construction expenses	0.39	0.34	0.41	R 21 157 203.40
Contractors fee	0.17	0.18	0.21	R 9 222 370.71
Contingency	0.34	0.36	0.42	R 18 444 741.43
				R 66 726 564.57
FCI				R 198 009 724.14
Initial Loan Amount - P				R 198 009 724.14
Interest rate per Period - r				10.50%
Number of Compounding Periods per year - m				12
Number of payment periods - n (years)				10
Total Compunding periods				120
Discounting factor				7%
Effective Annual interest rate - i_eff				11.02%
Future value - F				R 563 264 326.01
Payment Amount per period - A				R 2 671 844.15
Total Annual amount				R 32 062 129.79
Depreciation				R 19 800 972.41
Fixed Capital Investment				R 198 009 724.14
Salvage Value				
Life of Equipment				10
Manufacturing Costs	Minimum range	Maximum Range	Midpoint	Uses Midpoint Value
Direct Manufacturing Costs - DMC				R 86 808 902.85
Raw Materials				R 27 500 000.00
Waste Treatment				R 0.00
Utilities				R 3 197 429.48
Operating Labour				R 32 036 832.00
Direct Supervisory and Clerical Labour	0.1	0.25	0.175	R 5 606 445.60
Maintenance and Repairs	0.02	0.1	0.06	R 11 880 583.45
Operating Supplies	0.1	0.2	0.15	R 1 782 087.52
Laboritory Charges	0.1	0.2	0.15	R 4 805 524.80
Patents and Royalties	0	0.06	0.03	
Fixed manufacturing Cost - FMC				R 55 851 600.22
Depreciation			0.1	R 19 800 972.41
Local Taxes and Insurance	0.014	0.05	0.032	R 6 336 311.17
Plant Overhead Costs	0.5	0.7	0.6	R 29 714 316.63
General Expences -GE				R 36 334 357.14
Administration			0.15	R 7 428 579.16
Distribution and Selling	0.02	0.2	0.11	R 19 872 722.36
Research and Development			0.05	R 9 033 055.62
Cost of Manufacturing - COM				R 180 661 112.38
Cost of Manufacturing without depreciation - COM_d				R 160 860 139.97
Income				R 350 891 419.33

Figure C-28: Capex and Opex inputs as well as, Loan payment and Depreciation calculations for 100 000 ton Laminated Board scenario.

Appendix D NPV Analysis and results for all 28 scenarios

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 3 714 284.41	-R 3 714 284.41	1	-R 3 714 284.41	-R 3 714 284.41
1	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.934579	-R 2 516 170.92	-R 6 230 455.33
2	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.873439	-R 2 351 561.61	-R 8 582 016.94
3	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.816298	-R 2 197 721.13	-R 10 779 738.07
4	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.762895	-R 2 053 944.98	-R 12 833 683.06
5	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.712986	-R 1 919 574.75	-R 14 753 257.81
6	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.666342	-R 1 793 995.09	-R 16 547 252.90
7	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.62275	-R 1 676 630.93	-R 18 223 883.83
8	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.582009	-R 1 566 944.79	-R 19 790 828.62
9	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.543934	-R 1 464 434.39	-R 21 255 263.01
10	R 664 192.17	R 3 356 495.06	-R 2 692 302.89	R 371 428.44	R 0.00	R 0.00	-R 2 692 302.89	0.508349	-R 1 368 630.27	-R 22 623 893.28

Figure D-1: Charcoal 500 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 5 252 447.07	-R 5 252 447.07	1	-R 5 252 447.07	-R 5 252 447.07
1	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.934579	-R 3 567 959.74	-R 8 820 406.81
2	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.873439	-R 3 334 541.81	-R 12 154 948.62
3	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.816298	-R 3 116 394.21	-R 15 271 342.83
4	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.762895	-R 2 912 517.96	-R 18 183 860.79
5	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.712986	-R 2 721 979.40	-R 20 905 840.19
6	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.666342	-R 2 543 905.98	-R 23 449 746.17
7	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.62275	-R 2 377 482.23	-R 25 827 228.40
8	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.582009	-R 2 221 946.00	-R 28 049 174.40
9	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.543934	-R 2 076 585.05	-R 30 125 759.45
10	R 3 320 960.84	R 7 138 677.76	-R 3 817 716.92	R 525 244.71	R 0.00	R 0.00	-R 3 817 716.92	0.508349	-R 1 940 733.69	-R 32 066 493.14

Figure D-2: Charcoal 1000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 3 952 018.53	-R 3 952 018.53	1	-R 3 952 018.53	-R 3 952 018.53
1	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.934579	-R 2 905 479.92	-R 6 857 498.44
2	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.873439	-R 2 715 401.79	-R 9 572 900.24
3	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.816298	-R 2 537 758.68	-R 12 110 658.92
4	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.762895	-R 2 371 737.09	-R 14 482 396.01
5	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.712986	-R 2 216 576.72	-R 16 698 972.73
6	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.666342	-R 2 071 567.03	-R 18 770 539.75
7	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.62275	-R 1 936 043.95	-R 20 706 583.70
8	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.582009	-R 1 809 386.87	-R 22 515 970.57
9	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.543934	-R 1 691 015.77	-R 24 206 986.34
10	R 1 328 384.34	R 4 437 247.85	-R 3 108 863.51	R 395 201.85	R 0.00	R 0.00	-R 3 108 863.51	0.508349	-R 1 580 388.57	-R 25 787 374.90

Figure D-3: Charcoal 2500 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 8 610 345.22	-R 8 610 345.22	1	-R 8 610 345.22	-R 8 610 345.22
1	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.934579	-R 5 753 704.17	-R 14 364 049.39
2	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.873439	-R 5 377 293.62	-R 19 741 343.01
3	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.816298	-R 5 025 508.05	-R 24 766 851.06
4	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.762895	-R 4 696 736.50	-R 29 463 587.56
5	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.712986	-R 4 389 473.36	-R 33 853 060.93
6	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.666342	-R 4 102 311.56	-R 37 955 372.48
7	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.62275	-R 3 833 936.03	-R 41 789 308.52
8	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.582009	-R 3 583 117.79	-R 45 372 426.30
9	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.543934	-R 3 348 708.21	-R 48 721 134.52
10	R 6 641 921.68	R 12 798 385.15	-R 6 156 463.46	R 861 034.52	R 0.00	R 0.00	-R 6 156 463.46	0.508349	-R 3 129 633.84	-R 51 850 768.36

Figure D-4: Charcoal 5000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 22 941 402.43	-R 22 941 402.43	1	-R 22 941 402.43	-R 22 941 402.43
1	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.934579	-R 5 685 403.55	-R 28 626 805.98
2	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.873439	-R 5 313 461.26	-R 33 940 267.24
3	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.816298	-R 4 965 851.64	-R 38 906 118.88
4	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.762895	-R 4 640 982.84	-R 43 547 101.73
5	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.712986	-R 4 337 367.14	-R 47 884 468.87
6	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.666342	-R 4 053 614.15	-R 51 938 083.02
7	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.62275	-R 3 788 424.44	-R 55 726 507.47
8	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.582009	-R 3 540 583.59	-R 59 267 091.06
9	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.543934	-R 3 308 956.63	-R 62 576 047.68
10	R 13 283 362.07	R 19 366 743.86	-R 6 083 381.79	R 2 294 140.24	R 0.00	R 0.00	-R 6 083 381.79	0.508349	-R 3 092 482.83	-R 65 668 530.51

Figure D-5: Charcoal 10 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 64 573 000.53	-R 64 573 000.53	1	-R 64 573 000.53	-R 64 573 000.53
1	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.934579	R 6 838 786.49	-R 57 734 214.04
2	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.873439	R 6 391 389.24	-R 51 342 824.80
3	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.816298	R 5 973 260.97	-R 45 369 563.82
4	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.762895	R 5 582 486.89	-R 39 787 076.93
5	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.712986	R 5 217 277.47	-R 34 569 799.46
6	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.666342	R 4 875 960.25	-R 29 693 839.21
7	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.62275	R 4 556 972.20	-R 25 136 867.01
8	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.582009	R 4 258 852.52	-R 20 878 014.49
9	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.543934	R 3 980 236.00	-R 16 897 778.49
10	R 66 419 216.84	R 58 767 192.49	R 7 652 024.35	R 6 457 300.05	R 334 522.80	R 0.00	R 7 317 501.54	0.508349	R 3 719 846.73	-R 13 177 931.76

Figure D-6: Charcoal 50 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 97 874 541.48	-R 97 874 541.48	1	-R 97 874 541.48	-R 97 874 541.48
1	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.934579	R 26 711 973.51	-R 71 162 567.97
2	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.873439	R 24 964 461.23	-R 46 198 106.74
3	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.816298	R 23 331 272.17	-R 22 866 834.57
4	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.762895	R 21 804 927.27	-R 1 061 907.30
5	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.712986	R 20 378 436.70	R 19 316 529.40
6	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.666342	R 19 045 267.94	R 38 361 797.34
7	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.62275	R 17 799 315.83	R 56 161 113.17
8	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.582009	R 16 634 874.61	R 72 795 987.78
9	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.543934	R 15 546 611.79	R 88 342 599.57
10	R 132 838 433.67	R 96 947 705.20	R 35 890 728.47	R 9 787 454.15	R 7 308 916.81	R 0.00	R 28 581 811.66	0.508349	R 14 529 543.72	R 102 872 143.29

Figure D-7: Charcoal 100 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 2 198 410.66	-R 2 198 410.66	1	-R 2 198 410.66	-R 2 198 410.66
1	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.934579	-R 2 445 114.36	-R 4 643 525.02
2	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.873439	-R 2 285 153.61	-R 6 928 678.63
3	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.816298	-R 2 135 657.58	-R 9 064 336.21
4	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.762895	-R 1 995 941.66	-R 11 060 277.87
5	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.712986	-R 1 865 366.04	-R 12 925 643.91
6	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.666342	-R 1 743 332.75	-R 14 668 976.65
7	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.62275	-R 1 629 282.94	-R 16 298 259.59
8	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.582009	-R 1 522 694.34	-R 17 820 953.93
9	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.543934	-R 1 423 078.82	-R 19 244 032.75
10	R 376 363.64	R 2 992 636.00	-R 2 616 272.37	R 219 841.07	R 0.00	R 0.00	-R 2 616 272.37	0.508349	-R 1 329 980.20	-R 20 574 012.96

Figure D-8: Biochar 500 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 2 198 410.66	-R 2 198 410.66	1	-R 2 198 410.66	-R 2 198 410.66
1	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.934579	-R 2 251 433.39	-R 4 449 844.06
2	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.873439	-R 2 104 143.36	-R 6 553 987.41
3	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.816298	-R 1 966 489.12	-R 8 520 476.53
4	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.762895	-R 1 837 840.30	-R 10 358 316.83
5	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.712986	-R 1 717 607.75	-R 12 075 924.58
6	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.666342	-R 1 605 240.89	-R 13 681 165.48
7	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.62275	-R 1 500 225.13	-R 15 181 390.61
8	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.582009	-R 1 402 079.56	-R 16 583 470.17
9	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.543934	-R 1 310 354.73	-R 17 893 824.90
10	R 752 727.27	R 3 161 761.00	-R 2 409 033.73	R 219 841.07	R 0.00	R 0.00	-R 2 409 033.73	0.508349	-R 1 224 630.59	-R 19 118 455.49

Figure D-9: Biochar 1000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 2 198 410.66	-R 2 198 410.66	1	-R 2 198 410.66	-R 2 198 410.66
1	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.934579	-R 2 626 835.06	-R 4 825 245.73
2	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.873439	-R 2 454 986.04	-R 7 280 231.76
3	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.816298	-R 2 294 379.48	-R 9 574 611.24
4	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.762895	-R 2 144 279.88	-R 11 718 891.12
5	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.712986	-R 2 003 999.89	-R 13 722 891.02
6	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.666342	-R 1 872 897.09	-R 15 595 788.11
7	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.62275	-R 1 750 371.12	-R 17 346 159.23
8	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.582009	-R 1 635 860.86	-R 18 982 020.08
9	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.543934	-R 1 528 841.92	-R 20 510 862.01
10	R 1 881 818.18	R 4 692 531.70	-R 2 810 713.52	R 219 841.07	R 0.00	R 0.00	-R 2 810 713.52	0.508349	-R 1 428 824.23	-R 21 939 686.23

Figure D-10: Biochar 2500 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 2 198 410.66	-R 2 198 410.66	1	-R 2 198 410.66	-R 2 198 410.66
1	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.934579	-R 2 614 874.79	-R 4 813 285.46
2	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.873439	-R 2 443 808.22	-R 7 257 093.68
3	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.816298	-R 2 283 932.92	-R 9 541 026.59
4	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.762895	-R 2 134 516.74	-R 11 675 543.34
5	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.712986	-R 1 994 875.46	-R 13 670 418.80
6	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.666342	-R 1 864 369.59	-R 15 534 788.39
7	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.62275	-R 1 742 401.49	-R 17 277 189.87
8	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.582009	-R 1 628 412.60	-R 18 905 602.48
9	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.543934	-R 1 521 880.94	-R 20 427 483.41
10	R 3 763 636.36	R 6 561 552.39	-R 2 797 916.03	R 219 841.07	R 0.00	R 0.00	-R 2 797 916.03	0.508349	-R 1 422 318.63	-R 21 849 802.05

Figure D-11: Biochar 5000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 4 185 434.75	-R 4 185 434.75	1	-R 4 185 434.75	-R 4 185 434.75
1	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.934579	-R 1 352 848.54	-R 5 538 283.29
2	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.873439	-R 1 264 344.43	-R 6 802 627.72
3	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.816298	-R 1 181 630.31	-R 7 984 258.02
4	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.762895	-R 1 104 327.39	-R 9 088 585.41
5	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.712986	-R 1 032 081.67	-R 10 120 667.08
6	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.666342	-R 964 562.31	-R 11 085 229.39
7	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.62275	-R 901 460.10	-R 11 986 689.50
8	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.582009	-R 842 486.08	-R 12 829 175.57
9	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.543934	-R 787 370.17	-R 13 616 545.74
10	R 7 527 272.73	R 8 974 820.66	-R 1 447 547.94	R 418 543.48	R 0.00	R 0.00	-R 1 447 547.94	0.508349	-R 735 859.97	-R 14 352 405.71

Figure D-12: Biochar 10 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 11 851 989.20	-R 11 851 989.20	1	-R 11 851 989.20	-R 11 851 989.20
1	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.934579	R 4 572 212.12	-R 7 279 777.08
2	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.873439	R 4 273 095.44	-R 3 006 681.64
3	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.816298	R 3 993 547.14	R 986 865.50
4	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.762895	R 3 732 287.05	R 4 719 152.54
5	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.712986	R 3 488 118.73	R 8 207 271.27
6	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.666342	R 3 259 924.05	R 11 467 195.32
7	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.62275	R 3 046 657.99	R 14 513 853.32
8	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.582009	R 2 847 343.92	R 17 361 197.23
9	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.543934	R 2 661 069.08	R 20 022 266.31
10	R 37 636 363.64	R 31 302 459.10	R 6 333 904.54	R 1 185 198.92	R 1 441 637.57	R 0.00	R 4 892 266.97	0.508349	R 2 486 980.45	R 22 509 246.76

Figure D-13: Biochar 50 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 20 040 932.34	-R 20 040 932.34	1	-R 20 040 932.34	-R 20 040 932.34
1	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.934579	R 13 379 952.92	-R 6 660 979.42
2	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.873439	R 12 504 628.90	R 5 843 649.47
3	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.816298	R 11 686 569.06	R 17 530 218.53
4	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.762895	R 10 922 027.16	R 28 452 245.69
5	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.712986	R 10 207 502.02	R 38 659 747.71
6	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.666342	R 9 539 721.51	R 48 199 469.23
7	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.62275	R 8 915 627.58	R 57 115 096.81
8	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.582009	R 8 332 362.23	R 65 447 459.03
9	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.543934	R 7 787 254.42	R 73 234 713.45
10	R 75 272 727.27	R 56 168 000.17	R 19 104 727.11	R 2 004 093.23	R 4 788 177.48	R 0.00	R 14 316 549.62	0.508349	R 7 277 807.87	R 80 512 521.32

Figure D-14: Biochar 100 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 33 918 531.95	-R 33 918 531.95	1	-R 33 918 531.95	-R 33 918 531.95
1	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.934579	-R 15 067 013.21	-R 48 985 545.17
2	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.873439	-R 14 081 320.76	-R 63 066 865.92
3	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.816298	-R 13 160 112.86	-R 76 226 978.78
4	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.762895	-R 12 299 170.90	-R 88 526 149.68
5	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.712986	-R 11 494 552.24	-R 100 020 701.92
6	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.666342	-R 10 742 572.19	-R 110 763 274.10
7	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.62275	-R 10 039 787.09	-R 120 803 061.19
8	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.582009	-R 9 382 978.59	-R 130 186 039.78
9	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.543934	-R 8 769 138.87	-R 138 955 178.65
10	R 1 695 536.49	R 17 817 240.62	-R 16 121 704.14	R 3 391 853.20	R 0.00	R 0.00	-R 16 121 704.14	0.508349	-R 8 195 456.89	-R 147 150 635.53

Figure D-15: Activated carbon 500 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 33 918 531.95	-R 33 918 531.95	1	-R 33 918 531.95	-R 33 918 531.95
1	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.934579	-R 13 952 844.54	-R 47 871 376.49
2	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.873439	-R 13 040 041.62	-R 60 911 418.11
3	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.816298	-R 12 186 954.79	-R 73 098 372.90
4	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.762895	-R 11 389 677.37	-R 84 488 050.27
5	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.712986	-R 10 644 558.29	-R 95 132 608.57
6	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.666342	-R 9 948 185.32	-R 105 080 793.88
7	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.62275	-R 9 297 369.46	-R 114 378 163.34
8	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.582009	-R 8 689 130.33	-R 123 067 293.68
9	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.543934	-R 8 120 682.55	-R 131 187 976.23
10	R 3 391 072.98	R 18 320 616.63	-R 14 929 543.65	R 3 391 853.20	R 0.00	R 0.00	-R 14 929 543.65	0.508349	-R 7 589 422.95	-R 138 777 399.18

Figure D-16: Activated carbon 1000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 33 918 531.95	-R 33 918 531.95	1	-R 33 918 531.95	-R 33 918 531.95
1	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.934579	-R 10 610 338.51	-R 44 528 870.47
2	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.873439	-R 9 916 204.22	-R 54 445 074.68
3	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.816298	-R 9 267 480.58	-R 63 712 555.26
4	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.762895	-R 8 661 196.80	-R 72 373 752.06
5	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.712986	-R 8 094 576.45	-R 80 468 328.51
6	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.666342	-R 7 565 024.72	-R 88 033 353.23
7	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.62275	-R 7 070 116.56	-R 95 103 469.79
8	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.582009	-R 6 607 585.57	-R 101 711 055.36
9	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.543934	-R 6 175 313.62	-R 107 886 368.98
10	R 8 477 682.44	R 19 830 744.65	-R 11 353 062.21	R 3 391 853.20	R 0.00	R 0.00	-R 11 353 062.21	0.508349	-R 5 771 321.14	-R 113 657 690.11

Figure D-18: Activated carbon 2500 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 33 918 531.95	-R 33 918 531.95	1	-R 33 918 531.95	-R 33 918 531.95
1	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.934579	-R 5 039 495.14	-R 38 958 027.09
2	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.873439	-R 4 709 808.54	-R 43 667 835.63
3	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.816298	-R 4 401 690.22	-R 48 069 525.86
4	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.762895	-R 4 113 729.18	-R 52 183 255.04
5	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.712986	-R 3 844 606.71	-R 56 027 861.75
6	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.666342	-R 3 593 090.39	-R 59 620 952.14
7	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.62275	-R 3 358 028.40	-R 62 978 980.53
8	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.582009	-R 3 138 344.30	-R 66 117 324.83
9	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.543934	-R 2 933 032.05	-R 69 050 356.88
10	R 16 955 364.88	R 22 347 624.68	-R 5 392 259.80	R 3 391 853.20	R 0.00	R 0.00	-R 5 392 259.80	0.508349	-R 2 741 151.45	-R 71 791 508.34

Figure D-17: Activated carbon 5000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 35 139 300.65	-R 35 139 300.65	1	-R 35 139 300.65	-R 35 139 300.65
1	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.934579	R 4 330 646.58	-R 30 808 654.07
2	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.873439	R 4 047 333.25	-R 26 761 320.82
3	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.816298	R 3 782 554.44	-R 22 978 766.39
4	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.762895	R 3 535 097.60	-R 19 443 668.78
5	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.712986	R 3 303 829.54	-R 16 139 839.24
6	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.666342	R 3 087 691.16	-R 13 052 148.09
7	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.62275	R 2 885 692.67	-R 10 166 455.42
8	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.582009	R 2 696 909.04	-R 7 469 546.38
9	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.543934	R 2 520 475.74	-R 4 949 070.65
10	R 33 910 729.76	R 28 841 436.13	R 5 069 293.64	R 3 513 930.06	R 435 501.80	R 0.00	R 4 633 791.84	0.508349	R 2 355 584.80	-R 2 593 485.85

Figure D-19: Activated carbon 10 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 92 294 350.17	-R 92 294 350.17	1	-R 92 294 350.17	-R 92 294 350.17
1	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.934579	R 50 415 696.09	-R 41 878 654.09
2	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.873439	R 47 117 472.98	R 5 238 818.89
3	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.816298	R 44 035 021.47	R 49 273 840.36
4	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.762895	R 41 154 225.68	R 90 428 066.04
5	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.712986	R 38 461 893.16	R 128 889 959.20
6	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.666342	R 35 945 694.54	R 164 835 653.74
7	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.62275	R 33 594 107.05	R 198 429 760.78
8	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.582009	R 31 396 361.72	R 229 826 122.51
9	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.543934	R 29 342 394.14	R 259 168 516.64
10	R 169 553 648.81	R 98 219 547.42	R 71 334 101.40	R 9 229 435.02	R 17 389 306.59	R 0.00	R 53 944 794.81	0.508349	R 27 422 798.26	R 286 591 314.90

Figure D-20: Activated carbon 50 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 139 892 075.55	-R 139 892 075.55	1	-R 139 892 075.55	-R 139 892 075.55
1	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.934579	R 115 680 314.04	-R 24 211 761.51
2	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.873439	R 108 112 443.03	R 83 900 681.52
3	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.816298	R 101 039 666.39	R 184 940 347.91
4	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.762895	R 94 429 594.75	R 279 369 942.66
5	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.712986	R 88 251 957.71	R 367 621 900.37
6	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.666342	R 82 478 465.15	R 450 100 365.52
7	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.62275	R 77 082 677.71	R 527 183 043.24
8	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.582009	R 72 039 885.71	R 599 222 928.95
9	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.543934	R 67 326 995.99	R 666 549 924.94
10	R 339 107 297.63	R 172 633 744.97	R 166 473 552.66	R 13 989 207.56	R 42 695 616.63	R 0.00	R 123 777 936.03	0.508349	R 62 922 426.16	R 729 472 351.10

Figure D-21: Activated carbon 100 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 17 890 068.92	-R 17 890 068.92	1	-R 17 890 068.92	-R 17 890 068.92
1	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.934579	-R 12 906 757.03	-R 30 796 825.95
2	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.873439	-R 12 062 389.74	-R 42 859 215.69
3	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.816298	-R 11 273 261.44	-R 54 132 477.14
4	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.762895	-R 10 535 758.36	-R 64 668 235.49
5	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.712986	-R 9 846 503.14	-R 74 514 738.63
6	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.666342	-R 9 202 339.38	-R 83 717 078.02
7	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.62275	-R 8 600 317.18	-R 92 317 395.20
8	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.582009	-R 8 037 679.61	-R 100 355 074.80
9	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.543934	-R 7 511 850.10	-R 107 866 924.90
10	R 1 754 457.10	R 15 564 687.12	-R 13 810 230.02	R 1 789 006.89	R 0.00	R 0.00	-R 13 810 230.02	0.508349	-R 7 020 420.65	-R 114 887 345.56

Figure D-22: Laminated Board 2500 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 17 890 068.92	-R 17 890 068.92	1	-R 17 890 068.92	-R 17 890 068.92
1	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.934579	-R 11 425 138.24	-R 29 315 207.17
2	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.873439	-R 10 677 699.29	-R 39 992 906.46
3	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.816298	-R 9 979 158.22	-R 49 972 064.68
4	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.762895	-R 9 326 316.09	-R 59 298 380.77
5	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.712986	-R 8 716 183.26	-R 68 014 564.04
6	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.666342	-R 8 145 965.67	-R 76 160 529.70
7	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.62275	-R 7 613 052.03	-R 83 773 581.73
8	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.582009	-R 7 115 001.89	-R 90 888 583.62
9	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.543934	-R 6 649 534.48	-R 97 538 118.10
10	R 3 508 914.19	R 15 733 812.12	-R 12 224 897.92	R 1 789 006.89	R 0.00	R 0.00	-R 12 224 897.92	0.508349	-R 6 214 518.21	-R 103 752 636.31

Figure D-23: Laminated Board 1000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 17 890 068.92	-R 17 890 068.92	1	-R 17 890 068.92	-R 17 890 068.92
1	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.934579	-R 7 976 616.77	-R 25 866 685.69
2	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.873439	-R 7 454 782.03	-R 33 321 467.72
3	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.816298	-R 6 967 086.01	-R 40 288 553.72
4	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.762895	-R 6 511 295.33	-R 46 799 849.06
5	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.712986	-R 6 085 322.74	-R 52 885 171.80
6	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.666342	-R 5 687 217.52	-R 58 572 389.31
7	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.62275	-R 5 315 156.56	-R 63 887 545.87
8	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.582009	-R 4 967 436.03	-R 68 854 981.90
9	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.543934	-R 4 642 463.58	-R 73 497 445.48
10	R 7 706 207.17	R 16 241 187.12	-R 8 534 979.94	R 1 789 006.89	R 0.00	R 0.00	-R 8 534 979.94	0.508349	-R 4 338 751.01	-R 77 836 196.50

Figure D-24: Laminated Board 500 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 17 890 068.92	-R 17 890 068.92	1	-R 17 890 068.92	-R 17 890 068.92
1	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.934579	-R 8 208 849.99	-R 26 098 918.91
2	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.873439	-R 7 671 822.42	-R 33 770 741.32
3	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.816298	-R 7 169 927.49	-R 40 940 668.82
4	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.762895	-R 6 700 866.82	-R 47 641 535.63
5	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.712986	-R 6 262 492.35	-R 53 904 027.98
6	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.666342	-R 5 852 796.59	-R 59 756 824.57
7	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.62275	-R 5 469 903.35	-R 65 226 727.93
8	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.582009	-R 5 112 059.21	-R 70 338 787.14
9	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.543934	-R 4 777 625.43	-R 75 116 412.57
10	R 17 544 570.97	R 26 328 040.45	-R 8 783 469.48	R 1 789 006.89	R 0.00	R 0.00	-R 8 783 469.48	0.508349	-R 4 465 070.50	-R 79 581 483.06

Figure D-25: Laminated Board 5000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 44 423 344.72	-R 44 423 344.72	1	-R 44 423 344.72	-R 44 423 344.72
1	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.934579	-R 6 065 455.05	-R 50 488 799.77
2	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.873439	-R 5 668 649.58	-R 56 157 449.36
3	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.816298	-R 5 297 803.35	-R 61 455 252.70
4	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.762895	-R 4 951 218.08	-R 66 406 470.79
5	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.712986	-R 4 627 306.62	-R 71 033 777.41
6	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.666342	-R 4 324 585.63	-R 75 358 363.03
7	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.62275	-R 4 041 668.81	-R 79 400 031.84
8	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.582009	-R 3 777 260.57	-R 83 177 292.41
9	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.543934	-R 3 530 150.06	-R 86 707 442.47
10	R 35 089 141.93	R 41 579 178.84	-R 6 490 036.91	R 4 442 334.47	R 0.00	R 0.00	-R 6 490 036.91	0.508349	-R 3 299 205.67	-R 90 006 648.14

Figure D-26: Laminated Board 10 000 ton NPV calculations for feasibility analysis.

Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 130 637 698.71	-R 130 637 698.71	1	-R 130 637 698.71	-R 130 637 698.71
1	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.934579	R 20 322 869.24	-R 110 314 829.46
2	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.873439	R 18 993 335.74	-R 91 321 493.73
3	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.816298	R 17 750 781.06	-R 73 570 712.66
4	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.762895	R 16 589 515.01	-R 56 981 197.65
5	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.712986	R 15 504 219.64	-R 41 476 978.01
6	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.666342	R 14 489 924.90	-R 26 987 053.11
7	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.62275	R 13 541 985.88	-R 13 445 067.23
8	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.582009	R 12 656 061.57	-R 789 005.65
9	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.543934	R 11 828 094.93	R 11 039 089.28
10	R 147 195 235.71	R 122 073 548.88	R 25 121 686.84	R 13 063 769.87	R 3 376 216.75	R 0.00	R 21 745 470.09	0.508349	R 11 054 294.33	R 22 093 383.60

Figure D-27: Laminated Board 50 000 ton NPV calculations for feasibility analysis.

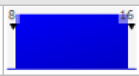
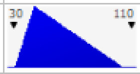
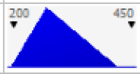
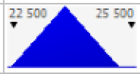
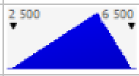
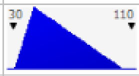
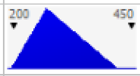
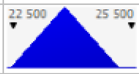
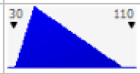
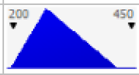
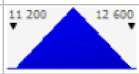
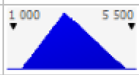
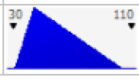
Year	Revenue from Annual Sales	Total Annual Expense	Annual Cash Flow	Annual Depreciation and Other Tax Allowances	Amount of Tax	Total Annual Capital Expenditure	Net Annual Cash Flow	Discount Factor	Net Annual Discounted Cash Flow	Net Present Value
0						R 198 009 724.14	-R 198 009 724.14	1	-R 198 009 724.14	-R 198 009 724.14
1	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.934579	R 111 478 560.72	-R 86 531 163.42
2	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.873439	R 104 185 570.77	R 17 654 407.35
3	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.816298	R 97 369 692.31	R 115 024 099.66
4	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.762895	R 90 999 712.44	R 206 023 812.09
5	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.712986	R 85 046 460.22	R 291 070 272.31
6	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.666342	R 79 482 673.10	R 370 552 945.41
7	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.62275	R 74 282 872.06	R 444 835 817.47
8	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.582009	R 69 423 244.91	R 514 259 062.39
9	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.543934	R 64 881 537.30	R 579 140 599.69
10	R 350 891 419.33	R 192 922 269.76	R 157 969 149.58	R 19 800 972.41	R 38 687 089.61	R 0.00	R 119 282 059.97	0.508349	R 60 636 950.75	R 639 777 550.44

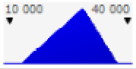
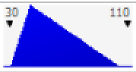
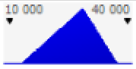
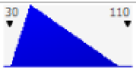
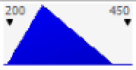
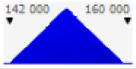
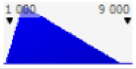
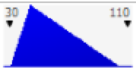
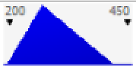
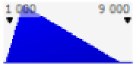
Figure D-28: Laminated Board 100 000 ton NPV calculations for feasibility analysis.

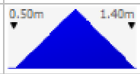
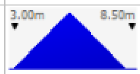
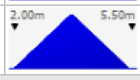
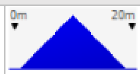
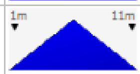
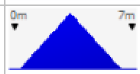
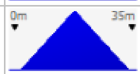
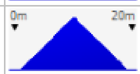
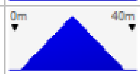
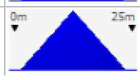
Appendix E Simulation inputs

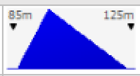
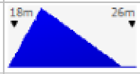
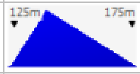
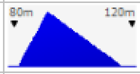
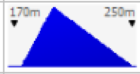
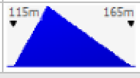
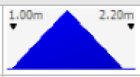
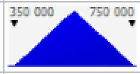
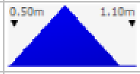
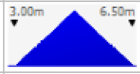
@RISK Model Inputs

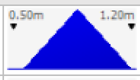
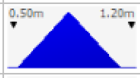
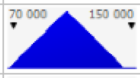
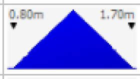
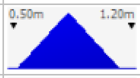
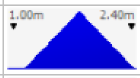
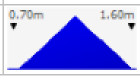
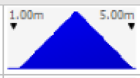
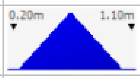
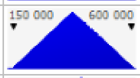
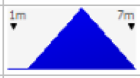
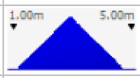
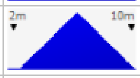
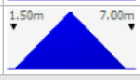
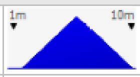
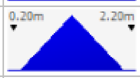
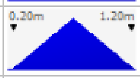
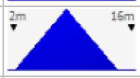
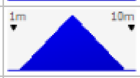
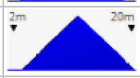
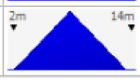
Performed By: Burger, MD, Mnr <17005019@sun.ac.za>
Date: 25 October 2017 03:36:28 PM

Name	Worksheet	Cell	Graph	Function	Min	Mean	Max
Category: <none>							
Lending rate 2	Intrest rate	N3		RiskUniform(8.4976,15.5024,RiskName(" Lending rate 2"))	8.4976	12	15.5024
Wage per hour	Charcoal (100 000)	M6		RiskTriang(L46,M46,N46,RiskStatic(M46))	34.42169	60.76305	101.3855
Raw material [per ton]	Charcoal (100 000)	M30		RiskTriang(L44,M44,N44,RiskStatic(M44))	R206.25	R297.92	R412.50
Product amount [ton]	Charcoal (100 000)	M33		RiskTriang(L47,M47,N47,RiskStatic(M47))	22581.82	23836.36	25090.91
Product selling price	Charcoal (100 000)	M34		RiskTriang(L45,M45,N45,RiskStatic(M45))	R2 647.14	R4 764.86	R6 353.14
Wage per hour	Biochar (100 000)	M6		RiskTriang(L42,M42,N42,RiskStatic(M42))	R34.42	R60.76	R101.39
Raw material [per ton]	Biochar (100 000)	M30		RiskTriang(L40,M40,N40,RiskStatic(M40))	R206.25	R297.92	R412.50
Product amount [ton]	Biochar (100 000)	M33		RiskTriang(L43,M43,N43,RiskStatic(M43))	22581.82	23836.36	25090.91
Product selling price	Biochar (100 000)	M34		RiskTriang(L41,M41,N41,RiskStatic(M41))	R1 500.00	R3 210.00	R5 130.00
Wage per hour	Biochar (50 000)	M6		RiskTriang(L41,M41,N41,RiskStatic(M41))	34.42169	60.76305	101.3855
Raw material cost [per ton]	Biochar (50 000)	M30		RiskTriang(L39,M39,N39,RiskStatic(M39))	R206.25	R297.92	R412.50
Product amount [ton]	Biochar (50 000)	M33		RiskTriang(L42,M42,N42,RiskStatic(M42))	11290.91	11918.18	12545.45
Product selling price	Biochar (50 000)	M34		RiskTriang(L40,M40,N40,RiskStatic(M40))	R1 500.00	R3 210.00	R5 130.00
Wage per hour	Activated Carbon (100 000)	M6		RiskTriang(M41,N41,O41,RiskStatic(N41))	34.42169	60.76305	101.3855

Raw material cost [per ton]	Activated Carbon (100 000)	M30		RiskTriang(M39,N39,O39,RiskStatic(N39))	R2 250.00	R3 250.00	R4 500.00
Product amount [ton]	Activated Carbon (100 000)	M33		RiskTriang(M42,N42,O42,RiskStatic(N42))	10696.65	11290.91	11885.17
Product selling price	Activated Carbon (100 000)	M34		RiskTriang(M40,N40,O40,RiskStatic(N40))	R14 265.99	R26 425.99	R36 480.00
Wage per hour	Activated Carbon (50 000)	M6		RiskTriang(L41,M41,N41,RiskStatic(M41))	34.42169	60.76305	101.3855
Raw material price [per ton]	Activated Carbon (50 000)	M30		RiskTriang(L39,M39,N39,RiskStatic(M39))	R2 250.00	R3 250.00	R4 500.00
Product amount [ton]	Activated Carbon (50 000)	M33		RiskTriang(L42,M42,N42,RiskStatic(M42))	5348.325	5645.455	5942.583
Product selling price	Activated Carbon (50 000)	M34		RiskTriang(L40,M40,N40,RiskStatic(M40))	R14 265.99	R26 425.99	R36 480.00
Wage per hour	Laminated Board (100 000)	M6		RiskTriang(L41,M41,N41,RiskStatic(M41))	34.42169	60.76305	101.3855
Raw material [per ton]	Laminated Board (100 000)	M30		RiskTriang(L39,M39,N39,RiskStatic(M39))	206.25	297.9167	412.5
Product amount [Boards]	Laminated Board (100 000)	M33		RiskTriang(L42,M42,N42,RiskStatic(M42))	142857.1	150793.7	158730.2
Product selling price	Laminated Board (100 000)	M34		RiskTriang(L40,M40,N40,RiskStatic(M40))	R1 105.31	R3 840.55	R8 205.72
Wage per hour	Laminated Board (50 000)	M6		RiskTriang(L41,M41,N41,RiskStatic(M41))	34.42169	60.76305	101.3855
Raw material [per ton]	Laminated Board (50 000)	M30		RiskTriang(L39,M39,N39,RiskStatic(M39))	206.25	297.9167	412.5
Product amount [boards]	Laminated Board (50 000)	M33		RiskTriang(L42,M42,N42,RiskStatic(M42))	71428.57	75396.83	79365.08
Product selling price	Laminated Board (50 000)	M34		RiskTriang(L40,M40,N40,RiskStatic(M40))	R1 105.31	R3 840.55	R8 205.72

Category: Direct Supervisory and Clerical Labour							
Direct Supervisory and Clerical Labour / Uses Midpoint Value	Charcoal (100 000)	F52		RiskTriang(H52,J52,I52,RiskStatic(J52))	R1 041 660.00	R1 822 905.00	R2 604 150.00
Direct Supervisory and Clerical Labour / Uses Midpoint Value	Biochar (100 000)	F52		RiskTriang(H52,J52,I52,RiskStatic(J52))	R555 552.00	R972 216.00	R1 388 880.00
Direct Supervisory and Clerical Labour / Uses Midpoint Value	Biochar (50 000)	F52		RiskTriang(H52,J52,I52,RiskStatic(J52))	R370 368.00	R648 144.00	R925 920.00
Direct Supervisory and Clerical Labour / Uses Midpoint Value	Activated Carbon (100 000)	F52		RiskTriang(H52,J52,I52,RiskStatic(J52))	R749 995.20	R1 312 492.00	R1 874 988.00
Direct Supervisory and Clerical Labour / Uses Midpoint Value	Activated Carbon (50 000)	F52		RiskTriang(H52,J52,I52,RiskStatic(J52))	R509 256.00	R891 198.00	R1 273 140.00
Direct Supervisory and Clerical Labour / Uses Midpoint Value	Laminated Board (100 000)	F52		RiskTriang(H52,J52,I52,RiskStatic(J52))	R3 203 683.00	R5 606 446.00	R8 009 208.00
Direct Supervisory and Clerical Labour / Uses Midpoint Value	Laminated Board (50 000)	F52		RiskTriang(H52,J52,I52,RiskStatic(J52))	R2 120 357.00	R3 710 625.00	R5 300 892.00
Category: Distribution and Selling							
Distribution and Selling / Uses Midpoint Value	Charcoal (100 000)	F65		RiskTriang(H65,J65,I65,RiskStatic(J65))	R1 817 742.00	R9 997 583.00	R18 177 420.00
Distribution and Selling / Uses Midpoint Value	Biochar (100 000)	F65		RiskTriang(H65,J65,I65,RiskStatic(J65))	R1 098 541.00	R6 041 973.00	R10 985 410.00
Distribution and Selling / Uses Midpoint Value	Biochar (50 000)	F65		RiskTriang(H65,J65,I65,RiskStatic(J65))	R611 371.20	R3 362 542.00	R6 113 712.00
Distribution and Selling / Uses Midpoint Value	Activated Carbon (100 000)	F65		RiskTriang(H65,J65,I65,RiskStatic(J65))	R3 279 427.00	R18 036 850.00	R32 794 270.00
Distribution and Selling / Uses Midpoint Value	Activated Carbon (50 000)	F65		RiskTriang(H65,J65,I65,RiskStatic(J65))	R1 850 090.00	R10 175 500.00	R18 500 900.00
Distribution and Selling / Uses Midpoint Value	Laminated Board (100 000)	F65		RiskTriang(H65,J65,I65,RiskStatic(J65))	R3 613 222.00	R19 872 720.00	R36 132 220.00
Distribution and Selling / Uses Midpoint Value	Laminated Board (50 000)	F65		RiskTriang(H65,J65,I65,RiskStatic(J65))	R2 279 684.00	R12 538 260.00	R22 796 840.00

Category: FCI							
FCI / Cost	Charcoal (100 000)	F28		RiskTriang(L48,M48,N48,RiskStatic(M48))	R88 087 090.00	R102 768 300.00	R122 343 200.00
FCI / Cost	Biochar (100 000)	F28		RiskTriang(L44,M44,N44,RiskStatic(M44))	R18 036 840.00	R21 042 980.00	R25 051 170.00
FCI / Cost	Biochar (50 000)	F28		RiskTriang(L43,M43,N43,RiskStatic(M43))	R10 666 790.00	R12 444 590.00	R14 814 990.00
FCI / Cost	Activated Carbon (100 000)	F28		RiskTriang(M43,N43,O43,RiskStatic(N43))	R125 902 900.00	R146 886 700.00	R174 865 100.00
FCI / Cost	Activated Carbon (50 000)	F28		RiskTriang(L43,M43,N43,RiskStatic(M43))	R83 064 910.00	R96 909 060.00	R115 367 900.00
FCI / Cost	Laminated Board (100 000)	F28		RiskTriang(L43,M43,N43,RiskStatic(M43))	R178 208 800.00	R207 910 200.00	R247 512 200.00
FCI / Cost	Laminated Board (50 000)	F28		RiskTriang(L43,M43,N43,RiskStatic(M43))	R117 573 900.00	R137 169 600.00	R163 297 100.00
Category: Laboritory Charges							
Laboritory Charges / Uses Midpoint Value	Charcoal (100 000)	F55		RiskTriang(H55,J55,I55,RiskStatic(J55))	R1 041 660.00	R1 562 490.00	R2 083 320.00
Laboritory Charges / Uses Midpoint Value	Biochar (100 000)	F55		RiskTriang(H55,J55,I55,RiskStatic(J55))	R555 552.00	R833 328.00	R1 111 104.00
Laboritory Charges / Uses Midpoint Value	Biochar (50 000)	F55		RiskTriang(H55,J55,I55,RiskStatic(J55))	R370 368.00	R555 552.00	R740 736.00
Laboritory Charges / Uses Midpoint Value	Activated Carbon (100 000)	F55		RiskTriang(H55,J55,I55,RiskStatic(J55))	R749 995.20	R1 124 993.00	R1 499 990.00
Laboritory Charges / Uses Midpoint Value	Activated Carbon (50 000)	F55		RiskTriang(H55,J55,I55,RiskStatic(J55))	R509 256.00	R763 884.00	R1 018 512.00
Laboritory Charges / Uses Midpoint Value	Laminated Board (100 000)	F55		RiskTriang(H55,J55,I55,RiskStatic(J55))	R3 203 683.00	R4 805 525.00	R6 407 367.00
Laboritory Charges / Uses Midpoint Value	Laminated Board (50 000)	F55		RiskTriang(H55,J55,I55,RiskStatic(J55))	R2 120 357.00	R3 180 535.00	R4 240 714.00

Category: Operating Supplies							
Operating Supplies / Uses Midpoint Value	Charcoal (100 000)	F54		RiskTriang(H54,J54,I54,RiskStatic(J54))	R587 247.30	R880 870.90	R1 174 495.00
Operating Supplies / Uses Midpoint Value	Biochar (100 000)	F54		RiskTriang(H55,J55,I55,RiskStatic(J55))	R555 552.00	R833 328.00	R1 111 104.00
Operating Supplies / Uses Midpoint Value	Biochar (50 000)	F54		RiskTriang(H54,J54,I54,RiskStatic(J54))	R71 111.94	R106 667.90	R142 223.90
Operating Supplies / Uses Midpoint Value	Activated Carbon (100 000)	F54		RiskTriang(H54,J54,I54,RiskStatic(J54))	R839 352.40	R1 259 029.00	R1 678 705.00
Operating Supplies / Uses Midpoint Value	Activated Carbon (50 000)	F54		RiskTriang(H54,J54,I54,RiskStatic(J54))	R553 766.10	R830 649.10	R1 107 532.00
Operating Supplies / Uses Midpoint Value	Laminated Board (100 000)	F54		RiskTriang(H54,J54,I54,RiskStatic(J54))	R1 188 058.00	R1 782 088.00	R2 376 117.00
Operating Supplies / Uses Midpoint Value	Laminated Board (50 000)	F54		RiskTriang(H54,J54,I54,RiskStatic(J54))	R783 826.20	R1 175 739.00	R1 567 652.00
Category: Local Taxes and Insurance							
Local Taxes and Insurance / Uses Midpoint Value	Charcoal (100 000)	F60		RiskTriang(H60,J60,I60,RiskStatic(J60))	R1 370 244.00	R3 131 985.00	R4 893 727.00
Local Taxes and Insurance / Uses Midpoint Value	Biochar (100 000)	F60		RiskTriang(H60,J60,I60,RiskStatic(J60))	R280 573.10	R641 309.80	R1 002 047.00
Local Taxes and Insurance / Uses Midpoint Value	Biochar (50 000)	F60		RiskTriang(H60,J60,I60,RiskStatic(J60))	R165 927.80	R379 263.70	R592 599.40
Local Taxes and Insurance / Uses Midpoint Value	Activated Carbon (100 000)	F60		RiskTriang(H60,J60,I60,RiskStatic(J60))	R1 958 489.00	R4 476 547.00	R6 994 604.00
Local Taxes and Insurance / Uses Midpoint Value	Activated Carbon (50 000)	F60		RiskTriang(H60,J60,I60,RiskStatic(J60))	R1 292 121.00	R2 953 419.00	R4 614 718.00
Local Taxes and Insurance / Uses Midpoint Value	Laminated Board (100 000)	F60		RiskTriang(H60,J60,I60,RiskStatic(J60))	R2 772 136.00	R6 336 311.00	R9 900 486.00
Local Taxes and Insurance / Uses Midpoint Value	Laminated Board (50 000)	F60		RiskTriang(H60,J60,I60,RiskStatic(J60))	R1 828 928.00	R4 180 406.00	R6 531 885.00
Category: Maintenance and Repairs							
Maintenance and Repairs / Uses Midpoint Value	Charcoal (100 000)	F53		RiskTriang(H53,J53,I53,RiskStatic(J53))	R1 957 491.00	R5 872 473.00	R9 787 454.00
Maintenance and Repairs / Uses Midpoint Value	Biochar (100 000)	F53		RiskTriang(H53,J53,I53,RiskStatic(J53))	R400 818.70	R1 202 456.00	R2 004 093.00
Maintenance and Repairs / Uses Midpoint Value	Biochar (50 000)	F53		RiskTriang(H53,J53,I53,RiskStatic(J53))	R237 039.80	R711 119.40	R1 185 199.00
Maintenance and Repairs / Uses Midpoint Value	Activated Carbon (100 000)	F53		RiskTriang(H53,J53,I53,RiskStatic(J53))	R2 797 842.00	R8 393 525.00	R13 989 210.00
Maintenance and Repairs / Uses Midpoint Value	Activated Carbon (50 000)	F53		RiskTriang(H53,J53,I53,RiskStatic(J53))	R1 845 887.00	R5 537 661.00	R9 229 435.00
Maintenance and Repairs / Uses Midpoint Value	Laminated Board (100 000)	F53		RiskTriang(H53,J53,I53,RiskStatic(J53))	R3 960 195.00	R11 880 580.00	R19 800 970.00
Maintenance and Repairs / Uses Midpoint Value	Laminated Board (50 000)	F53		RiskTriang(H53,J53,I53,RiskStatic(J53))	R2 612 754.00	R7 838 262.00	R13 063 770.00

Appendix F Simulation results not displayed in the discussion

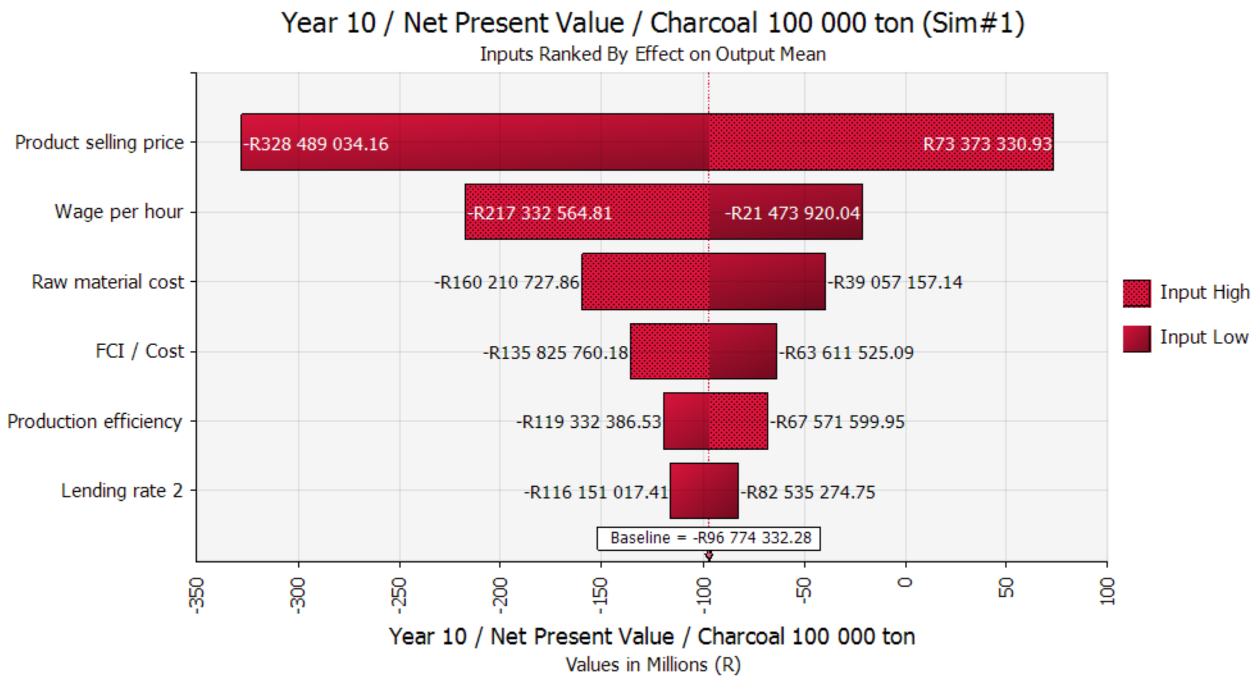


Figure F-1: The tornado plot displays the sensitivity analysis for the Charcoal value adding system for the 100 000 ton scenario.

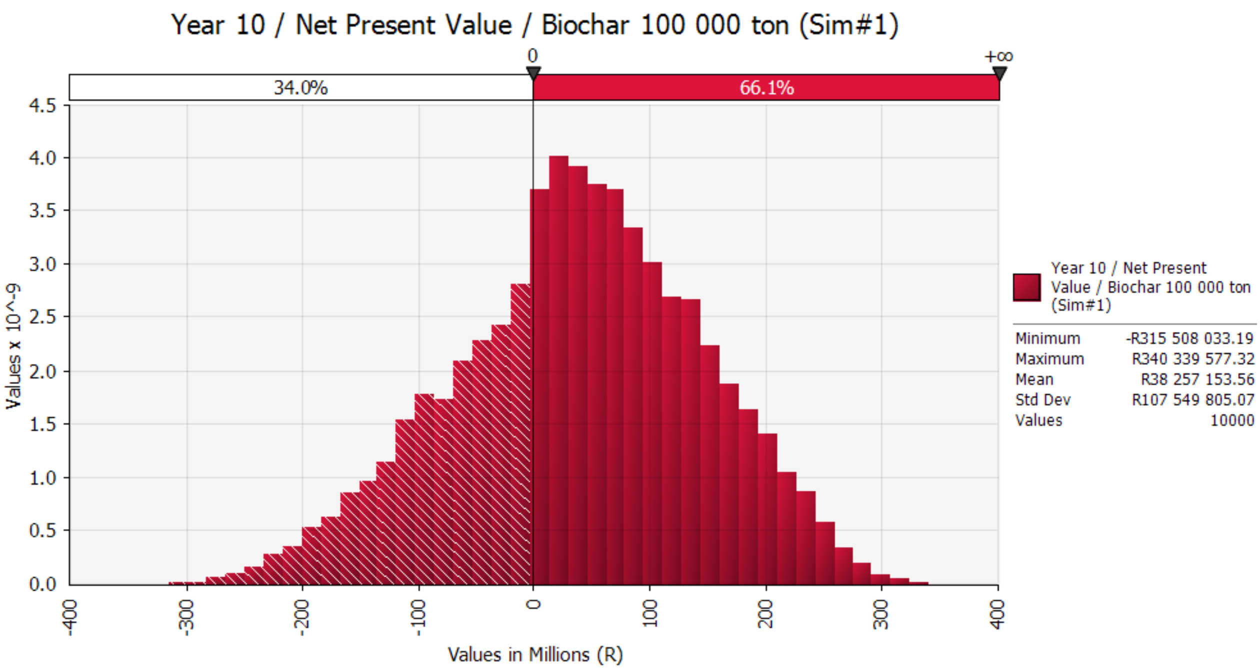


Figure F-2: The probability distribution of the Biochar value adding system for the 100 000 ton scenario.

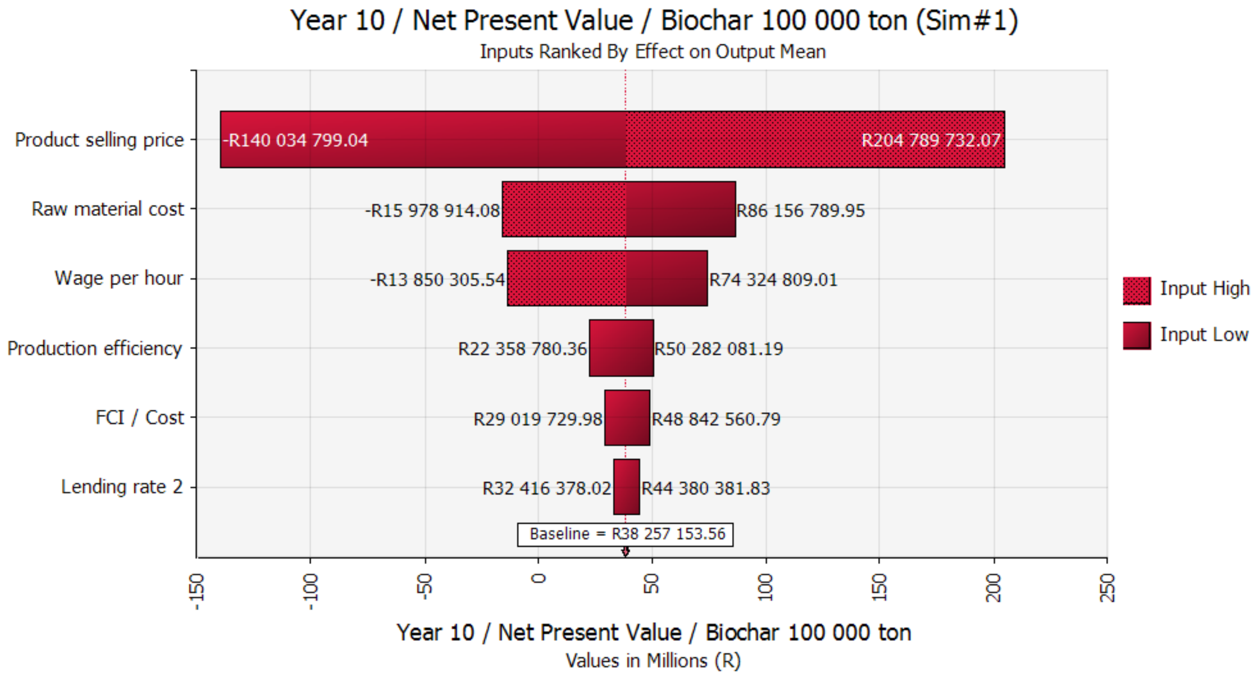


Figure F-3: The tornado plot displays the sensitivity analysis for the Biochar value adding system for the 100 000 ton scenario.

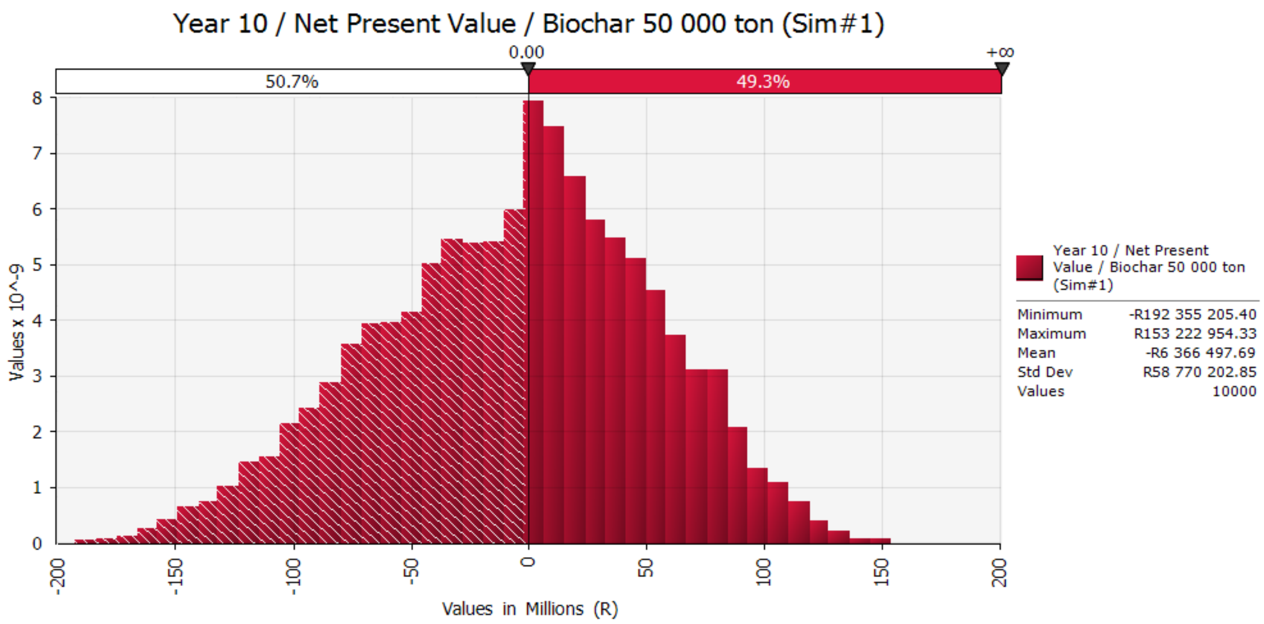


Figure F-4: The probability distribution of the Biochar value adding system for the 50 000 ton scenario.

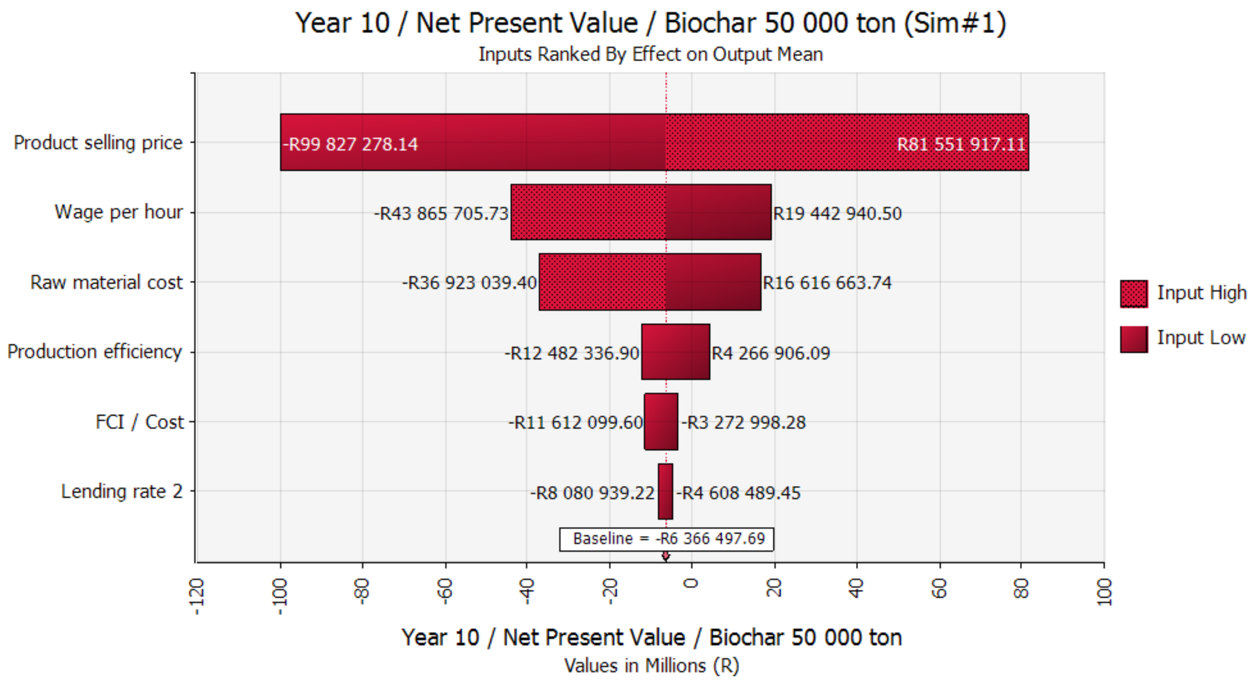


Figure F-5: The tornado plot displays the sensitivity analysis for the Biochar value adding system for the 50 000 ton scenario.

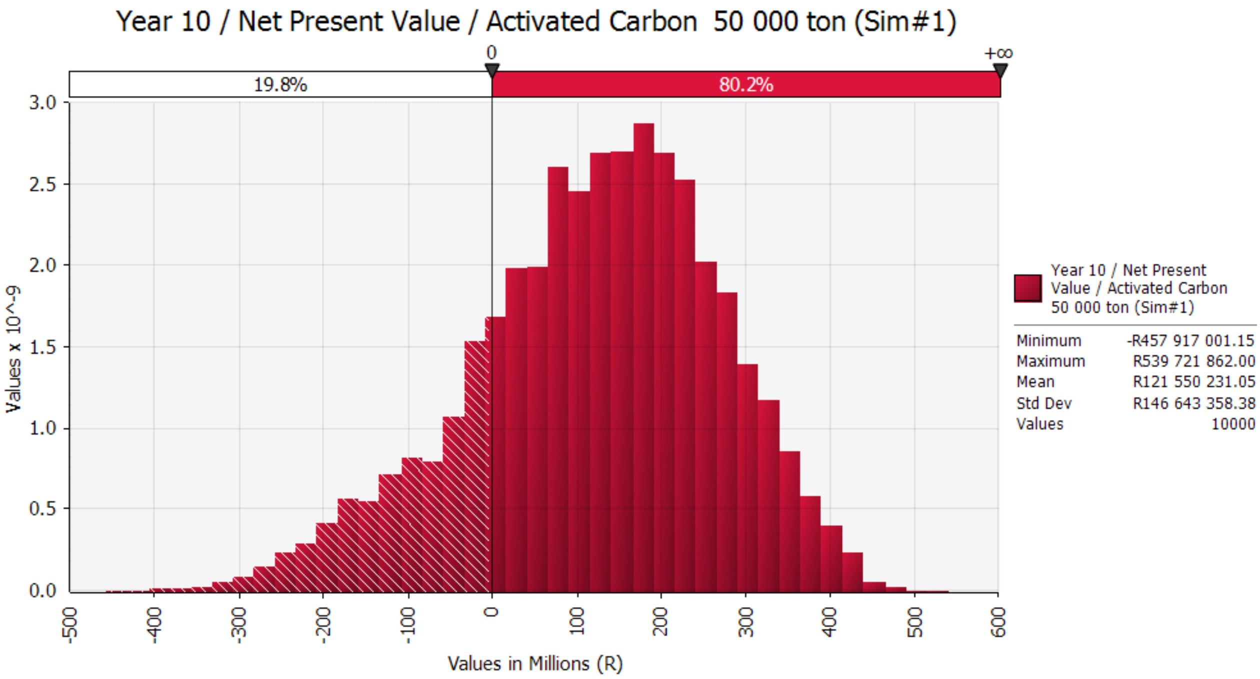


Figure F-6: The probability distribution of the Activated Carbon value adding system for the 50 000 ton scenario.

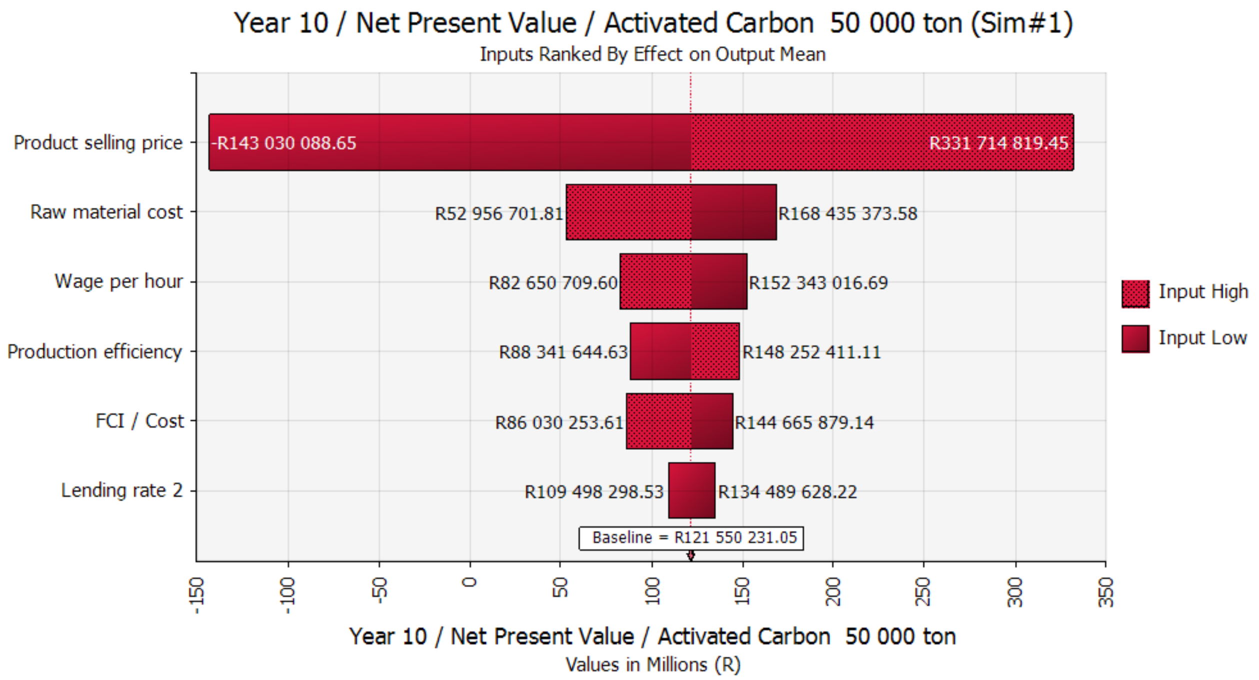


Figure F-7: The tornado plot displays the sensitivity analysis for the Laminated Board value adding system for the 50 000 ton scenario.

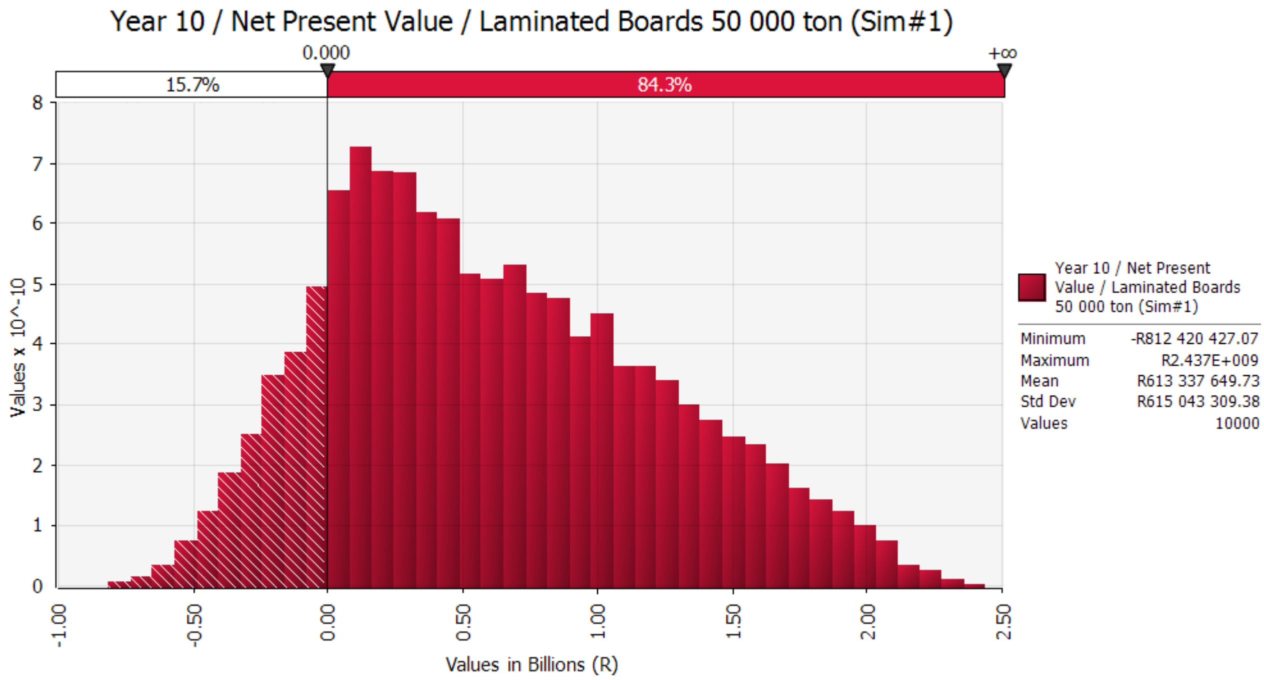


Figure F-8: The probability distribution of the Laminated Board value adding system for the 50 000 ton scenario

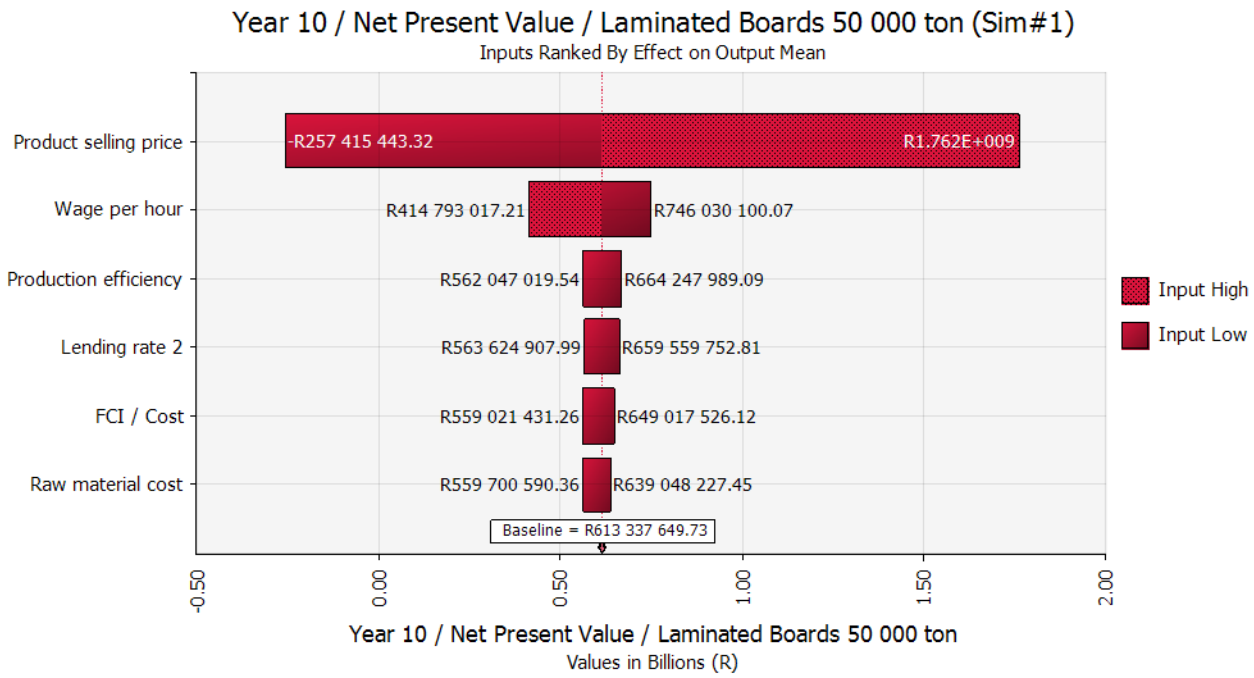
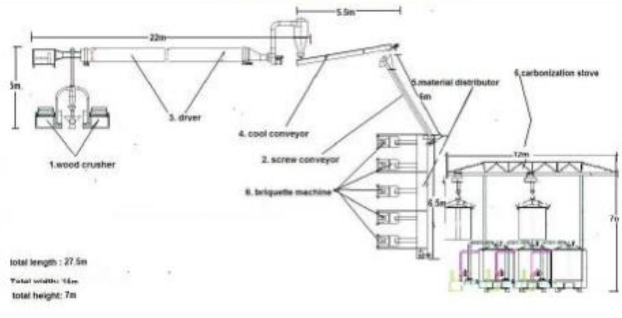


Figure F-9: The tornado plot displays the sensitivity analysis for the Laminated Board value adding system for the 50 000 ton scenario.

Appendix G Quotations

G.1 Charcoal process line quotation

	Client	Supplier
Company		Gongyi Xiaoyi Mingyang Machinery Plant
Address		Nanhuan Road, Gongyi City, Henan Province, China
Contact	Manager: Mr. Dewald Burger	Sales Manager: Ms. Bella Ren
Cellphone	0027-738054005	0086-15039052281/008613838391770
Email	rsabamboo@gmail.com	bella@zgmingyang.com



The steps are below for the whole line:

1. Using the crusher to crush the bamboo to powder directly;
2. Use the feeding conveyor to send the crushed powder to the dryer machine;
3. Use the cooling conveyor and feeding conveyor to send the dried powder to the material distributor;
4. Use the material distributor to send the material to the briquette machines and let the briquette machines work together;
5. Use the net conveyor to collect the briquette and send the briquette to the ground;
6. Use the carbonization furnace to make the charcoal briquette.

Quotation of the bamboo charcoal briquette product line

This line is based on the raw material is bamboo, and per day to work 8hours for the crusher to briquette machine, and the carbonizaiton furnace work 24hours. And if there is any questions, please feel free to contact me! Thanks!

Item	Machine name	Main data	Unit EXW price	QTY	Total EXW PRICE	Machine picture
Section A: Crushing part						
This crusher has two mouths, and it's the mulfunction type, and it can crush the wood within 230mm size to powder directly. And the final product size is within 5mm size.						
1	Wood crusher	1.Power: 55kw(main power)+7.5kw(fan motor)+0.75kw(air locker motor) 2.Capacity: 2500-3000kg/h 3.Weight: 1500kg 4.Voltage: 380v 50hz 3phase	$6152/SET	4 SETS	$24,608	
Section B: Drying part						
This sawdust dryer can dry the material with high moisture to 8-12% to suit the briquette machine						
2	Feeding conveyor(3m)	1.Power: 1.5kw 2.Capacity:can be adjust 3.Weight: 350kg 4.Voltage: 380v 50hz 3phase	$819/SET	4 SETS	$3,276	
3	Sawdust dryer GT-1800	1.Power: 15+3kw 2.Capacity: 2500-3000kg/h 3.Size: Roller diameter 1.8m, length 12m 4.Weight: 1500kg 5.Voltage: 380v 50hz 3phase	$27842/SET	4 SETS	$111,368	
Section C: Briquetting part						
This cooling conveyor can let the dried material cool down, and send to the feeding conveyor. This feeding conveyor is to send the cooled material to the material distributor. This material distributor can send the material to the briquette machine directly. thebriquette machine can make the briquette directly and the final product shape can be square, hexagon,round, octagon etc; the size can be customized. This net conveyor is to collect the briquette together and then send them to the ground.						
4	Cooling conveyor(6m)	1.Power: 3kw 2.Capacity:can be adjust 3.Weight: 650kg 4.Voltage: 380v 50hz 3phase	$1638/SET	3 SETS	$4,914	
5	Feeding conveyor(5m)	1.Power: 2.2kw 2.Capacity:can be adjust 3.Weight: 550kg 4.Voltage: 380v 50hz 3phase	$1365/SET	3 SETS	$4,095	

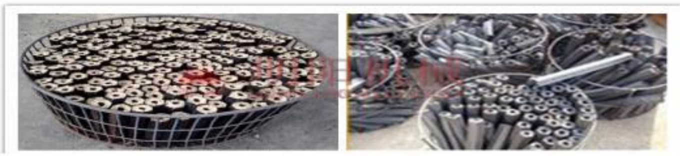
6	Material distributor(7m)	1.Power: 5.5kw 2.Capacity:can be adjust 3.Weight: 750kg 4.Voltage: 380v 50hz 3phase	$1911/SET	3 SETS	$5,733	
7	Wood sawdust briquette machine ZBJ50-C	1.Power: 22 kw 2.Capacity: 350-420kg/h 3.Machine size: 2.7*0.7*1.55m 4.Weight: 750kg 5.Voltage: 380v 50hz3phase 6.This machine can make the briquette with 50mm	$4179/SET	30 SETS	$125,370	
						
8	Net conveyor with smoke collector(7m)	1.Power: 5.5kw+0.22kw 2.Capacity:can be adjust 3.Weight: 750kg 4.Voltage: 380v 50hz 3phase	$1911/SET	6 SETS	$11,466	

Section D: Carbonizing part						
9	Charcoal carbonizaiton furnace QHL-4	1.Power: 1.5 kw+0.22kw 2.Capacity: 9.6t/day 3.Weight: 14000kg 4.Voltage: 380v 50hz3phase 6.It consists four outer stoves, twelves inner stoves, twelves covers and purification tanks and hoist	$33402/SE	3 SETS	$100,206	
10	Charcoal carbonizaiton furnace QHL-2	1.Power: 1.5 kw+0.22kw 2.Capacity: 4.8t/day 3.Weight: 7000kg 4.Voltage: 380v 50hz3phase 6.It consists two outer stoves, six inner stoves, six covers and purification tanks and hoist	$16701/SE	1 SET	$16,701	
Wood briquette						Wood briquette charcoal
Wood log						Wood log charcoal

Coconut shell						Coconut shell charcoal
Bamboo						Bamboo charcoal
Section E: Operating part						
11	Electric control cabinet		$4482/SET	3 SETS	$13,446	
12	**Total EXW**	**Total power:1064.3kw**		**64SETS**	**$421,183**	
Total EXW amount: USD 421183 EXW PRICE						
TOTAL EXW AMOUNT: EXW PRICE FOUR HUNDRED AND TWENTY ONE THOUSAND ONE HUNDRED AND EIGHTY THREE US DOLLARS ONLY						
Notice						

G.2 Biochar process line quotation

	Buyer	Seller
Company	The soucing	Gongyi Xiaoyi Mingyang Machinery Plant
Address		Nanhuan RD, Gongyi City, Henan Province, China
Sales Manager	Mr. Dewald Burger	Ms. Bella Ren
Phone	0027-738054005	0086 15039052281/0086-13838391770
Email	rsabamboo@gmail.com	bella@zgmingyang.com

Quotation of the wood charcoal carbonization furnace							
Item	Machine type	Main data	Consisting	Unit EXW PRICE	QTY	**Total EXW**	Machine picture
Section 1: Carbonization process							
This process is to carbonize the bamboo to biocahr first. This capacity is according to the bamboo cut into pieces and put them in the furnace.							
A: To put 33 tons raw bamboo into the furnace to make the biochar, you need two sets QHL-4							
1	QHL-4	1.Power: 1.5+0.22kw 2.Capacity: 6-7.2 t/day 3.Weight: 14000kg 4.Size:16*4*8m 5.Voltage: 380v 50hz 3phase **6.Packing in one 40 feet container**	four outer stoves, twelves inner stoves, twelves covers, one hoist and purification tanks	$33402/SET	2SETS	**$66,804**	
B: To put 165 tons raw bamboo into the furnace to make the biochar, you need 10 sets QHL-4							
1	QHL-4	1.Power: 1.5+0.22kw 2.Capacity: 6-7.2 t/day 3.Weight: 14000kg 4.Size:16*4*8m 5.Voltage: 380v 50hz 3phase **6.Packing in one 40 feet container**	four outer stoves, twelves inner stoves, twelves covers, one hoist and purification tanks	$33402/SET	10SETS	**$334,020**	
C: To put 330 tons raw bamboo into the furnace to make the biochar, you need 20 sets QHL-4							
1	QHL-4	1.Power: 1.5+0.22kw 2.Capacity: 6-7.2 t/day 3.Weight: 14000kg 4.Size:16*4*8m 5.Voltage: 380v 50hz 3phase **6.Packing in one 40 feet container**	four outer stoves, twelves inner stoves, twelves covers, one hoist and purification tanks	$33402/SET	20SETS	**$668,040**	
Raw material before and after using the carbonization furnace							
These raw materials suit the gas flow type carbonization furnace and energy saving carbonization furnace. ANd the raw material can be: wood, tree, branch, log, coconut shell, nuts shell, bamboo, wood briquette etc.							
Raw material before and after using the carbonization furnace							
Wood briquette							Wood briquette charcoal

Wood log		Wood log charcoal
Coconut shell		Coconut shell charcoal
Bamboo		bamboo charcoal

Section 2: Crushing part

This crusher is to crush the biochar getting from the Section 1 to powder(3-5mm) directly.

2	Charcoal crusher	1.Power: 18.5kw 2.Capacity: 1-3t/h 3.Weight: 610kg 4.Size:16*4*8m 5.Voltage: 380v 50hz 3phase	crusher, cyclone, dust collector and air locker	$3986/SET	1 SET	**$3,986**	

Note

1. Payment terms: 50% T/T down payment and 50% T/T balance payment before delivery;
2. This is price is EXW price;
3. Validity detailed: This price validity is one month;

Contact information

Sales Manager: Ms. Bella Ren
Cell: 008615039052281
Email: bella@zgmingyang.com
Phone: 0086-371-86051305
Skype: bella616919
Wechat: 008615039052281
Whatsapp: 008615039052281

G.3 Activated carbon process line quotation

上海戴沃机械科技有限公司
Shanghai Daiwo Machinery Technology Co.,LTD

Quotation List

SHANGHAI DAIWO MACHINERY TECHNOLOGY CO.,LTD

Add: No.7469, Dongchuan Rd, Pudong New District, Shanghai, China

Contact： Wendy

Mob: +0086 177 9690 0107

Whatsapp/Skype: +86 177 9690 0107

Tel： 021-58991002

Fax： 021-50676923

E-Mail： cherry@daiwomining.com

上海戴沃机械科技有限公司
Shanghai Daiwo Machinery Technology Co.,LTD

I. Activation process

Coconut Shell Based Activated Carbon Plant Equipment List&Price

1	Bucket elevator	ø 250*7m	3	1	2,190	2,190
2	Hopper	ø 2*4m	~	1	1,460	1,460
3	Slanted bucket elevator	ø 250*6m	1.5	1	4,380	4,380
4	Activation kiln	ø 1.9*14m	7.5	1	136,060	136,060
Activation kiln includes all refractory materials, heat-proof steel(310S), a high pressure blower(1.5 kw)						
5	Cooler	ø 600*5m	1.5	1	10,220	10,220
6	Belt conveyor(with high intensity magnetic roller)	500*4m	1.5	1	1,750	1,750
7	Incinerator	ø 2m*3.5m	~	1	7,280	7,280
8	Boiler	0.5 CBM	11	1	43,070	43,070
9	Water treatment	1 t/h	3	1	4,380	4,380
10	Cyclone	ø 900	~	1	2,190	2,190
11	Bag filter	64-1	7.5	1	10,950	10,950
12	Air pump		7.5	1	1,020	1,020
13	Control cabinet	CHNT	45.5	1	5,110	5,110
Sub-total amount in FOB Shanghai basis for activation process:$230,060						
II. Acid washing process						
1	Acid wash tank	1.3m*1.3m*1.1m	~	10	2,190	21,900
2	Acid proof pump	~	1	4	1,460	5,840
3	External heat rotary	ø 1000*12m	5.5	1	51,095	51,095

2

上海戴沃机械科技有限公司
Shanghai Daiwo Machinery Technology Co., LTD

	dryer(stainless steel constructed)					
4	Dryer heating system	~	~	1	21,900	21,900
5	Cooler	ø 600*5	1.5	1	10,220	10,220
6	Belt conveyor	B500*4	1.5	1	1,460	1,460
7	Cyclone(6mm thickness, with acid proof material)	ø 900	~	2	2,920	5,840
8	Bag filter	64-1	7.5	1	10,950	10,950
9	Air pump	~	7.5	1	1,020	1,020
10	Control cabinet	CHNT	27.5	1	2,920	2,920
Sub-total amount in FOB Shanghai basis for acid washing process:$133,145						
III. Classification process						
1	Bucket elevator	ø 200*7m	3	2	3,800	7,600
2	Roller crusher	ø 200*600	5.5	2	7,300	14,600
3	Linear screen	1m*3.5m	3	2	17,520	35,040
4	Hopper	ø 1*1.5m	~	2	730	1,460
5	Cyclone	ø 900	~	1	2,190	2,190
6	Bag filter	64-1	7.5	1	10,950	10,950
7	Air pump	~	7.5	1	1,020	1,020
8	Screw conveyor	ø 250*2	1.5	1	2,190	2,190
9	Raymond mill	YGM9517	37+37+5.5	1	27,500	27,500
10	Cyclone	ø 900	~	1	2,190	2,190
11	Bag filter	DMC32	3	1	3,990	3,990
12	Mixer	Ø2.2*5.2	7.5	1	8,760	8,760

上海戴沃机械科技有限公司
Shanghai Daiwo Machinery Technology Co.,LTD

13	Hopper	1.2*1.2*1.3	~	1	1,125	1,125
14	Vacuum type packing machine	JKF-159H	8	1	13,530	13,530
15	Control cabinet	CHNT	137.5	1	2,750	2,750
Sub-total amount in FOB Shanghai basis for classification process:$134,895						
Total amount in FOB Shanghai basis(US dollars): $498,100.00						
The above mentioned quotation includes the services for technical support, installation guidance, plant commissioning, and staff training, etc						
Selective purchasing:						
Connection pipes, steel structures, etc, around 20 tons				$21,900		
Installation tools&accessories				$14,600		
Laboratory equipment for final product testing				$21,900		

Commercial terms:

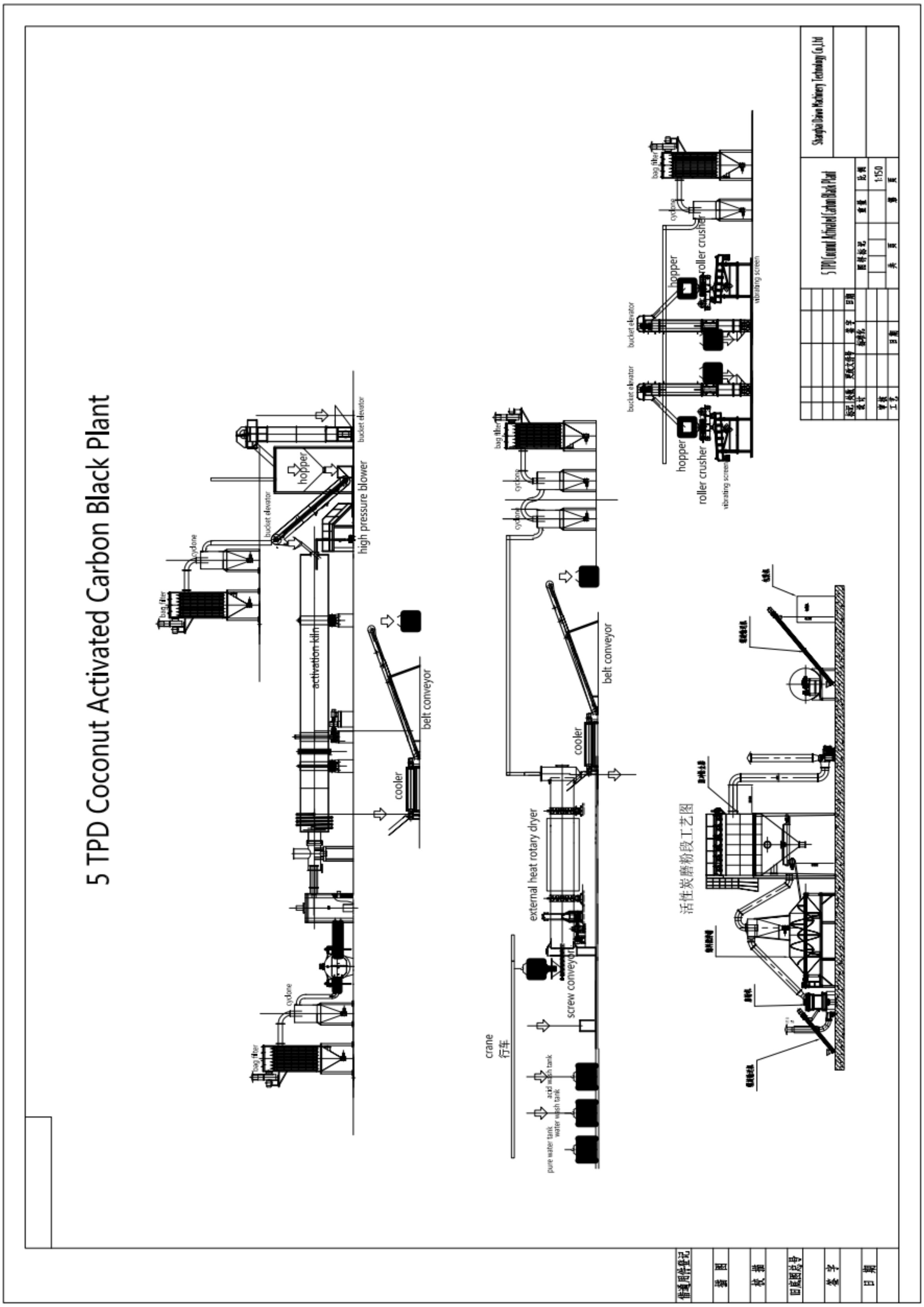
1.**Payment:** 30% of the total amount shall be paid by T/T as deposit, another 30% of the total amount to be paid after 30-35 days when contract in effect, 37% to be paid before delivery and balance paid after commissioning.
2.**Delivery:120** working days after receiving the advance payment.
3.**Packing**: Machines will be through rusty and moist-proof protection before delivery; small parts are packed into wooden crates; larger parts are wrapped by plastic sheetings.
4.**Installation:** Services of skilled technician(s) to supervise the assembly, installation, commissioning and train the local staff will be supplied after the seller confirms the preparation for installation is ready in the buyer's site. The buyer should prepare the necessary materials, tools, labours and offer necessary assistance. The reasonable local cost of the technician(s) during installation period including the accommodation, round-trip air ticket, insurance, communication fee, etc. are on the account of the buyer. 5 people will be assigned for installation, commissioning and training works. General engineer and two installation technicians will stay all along until works done. The other two engineers for refractory firebrick materials will stay 10 days. The buyer will pay the extra cost, for salary $67 per person each working day(except the general engineer).
5.**Warranty:** 100% brand new when leaving the factory. The seller guarantee the quality of the machine(excluding wearing parts) for a period of one year from the date of trial run but not exceed 15 months from the date on which machine shipped out of the factory.

6.**Period of validity:** This quotation is valid in 30 days since issued.

4

上海戴沃机械科技有限公司
Shanghai Daiwo Machinery Technology Co., LTD

5


5 TPD Coconut Activated Carbon Black Plant
bag filter
cyclone
bucket elevator
hopper
high pressure blower
activation kiln
belt conveyor
cooler
external heat rotary dryer
screw conveyor
crane
行车
acid wash tank
water wash tank
pure water tank
roller crusher
vibrating screen
活性炭磨粉段工艺图
1:150

G.4 Laminated Board process line quotation

Bamboo Big Board Making Machines P. 1 of 3

CHIN YUNG BAMBOO & WOOD CO., LTD.

錦榮竹木企業股份有限公司
彰化縣鹿港鎮民族路97號
NO.97, MIN TSU RD., LUKANG CHEN,
CHANG HUA HSIEN, TAIWAN, R.O.C
Tel: +886 4 777 6868
Fax: +886 4 778 3909, 777 2799
e-mail:cybamboo@ms2.hinet.net

OFFER SHEET

Messrs.: **RSA Bamboo (South Africa)** Date: JUNE 13, 2017

Dear Dewald Burger,

It is our pleasure to offer you based on the terms & conditions as stipulated hereunder:

1.Time of shipment: Within 75 days after receipt of your deposit

2.Term of delivery: F.O.B. TAIWAN PORT

3.Term of payment: By T/T (1) 40% deposit upon order; (2) 60% before shipment

4.Packing: By standard wooden cases/ pallet/ crate

5.Time of validity: Within 60 days after quoting date.

Model No.	Description	Q'TY	Unit	Unit Price(USD)	Amount(USD)
1 Solid Bamboo Big Board Making Machines					
CYM-101	BIG TYPE ROUND BAMBOO CROSS CUTTING MACHINE	1	set	1,230.00	1,230.00
CYM-102	OUTSIDE BAMBOO KNOT REMOVING MACHINE, 2.5M	1	set	4,180.00	4,180.00
CYM-103	BAMBOO SAWING & SIZING MACHINE, 2.5M	4	sets	2,850.00	11,400.00
CYM-104	BAMBOO STRIP 2-SIDES REMOVING MACHINE	2	sets	9,750.00	19,500.00
CYM-106	4-SIDES PLANING MACHINE	3	sets	10,820.00	32,460.00
CYM-006F	STICK SIZING MACHINE 8'	1	set	2,120.00	2,120.00
CYM-109	AUTOMATIC GLUE MIXING, FEEDING & APPLYING MACHINE	1	set	8,780.00	8,780.00
CYM-110XL	BAMBOO FLOOR AND BOARD JOINING MACHINE 4' X 8' (1-Layer)	1	set	79,560.00	79,560.00
CYM-111	SANDER 4' (HEAVY DUTY)	1	set	31,360.00	31,360.00
CYM-108	CARBON BOILER 3M (STAINLESS STEEL)	1	set	20,900.00	20,900.00
CYM-083LF	DRYER (USE BAMBOO OR WOOD WASTE, WITHOUT WOODEN PACKING)	2	sets	9,460.00	18,920.00
CYM-068F	MULTIPLE GRINDING MACHINE	1	set	5,560.00	5,560.00
CYM-064	DUST COLLECTOR	5	sets	880.00	4,400.00
CYM-130	FINGER SHAPING MACHINE	1	set	9,780.00	9,780.00
CYM-129	FINGER JOINTING MACHINE	1	set	14,260.00	14,260.00
CYM-191WA	STEAM BOILER (USE SAWDUST AS FUEL), 0.5 TON	1	set	18,200.00	18,200.00

錦榮竹木企業股份有限公司
彰化縣鹿港鎮民族路97號
NO.97, MIN TSU RD., LUKANG CHEN,
CHANG HUA HSIEN, TAIWAN, R.O.C
Tel: +886 4 777 6868
Fax: +886 4 778 3909, 777 2799
e-mail:cybamboo@ms2.hinet.net

CHIN YUNG BAMBOO & WOOD CO., LTD.

OFFER SHEET

Messrs.: **RSA Bamboo (South Africa)** Date: JUNE 13, 2017

CYM-190-1	Stainless Steel STEAM BOILING TANK (OUTSIDE) 2480x1380x1500mm	2	sets	3,900.00	7,800.00
CYM-190-2	Stainless Steel STEAM BOILING BASKET (INSIDE) 2400x1200x1400mm	2	sets	2,380.00	4,760.00
	SUBTOTAL (bamboo big board production line):	**31**	**sets**		**295,170.00**

****capacity: 24 ~32 pieces of bamboo big board (4' x 8' x 40mm)/ 16 hours, bamboo consumption: 576 ~ 768 poles, bamboo spec.: 6M long, diameter: 10cm, wall thickness: 7-8mm, bamboo poles should be in age of over than 4 years.**

2. BAMBOO VENEER MAKING MACHINE

CYM-031AB	BAMBOO VENEER PEELING MACHINE 1.5'	1	set	15,820.00	15,820.00
CYM-066A	SURFACE GRINDING MACHINE 1.5'	1	set	4,850.00	4,850.00
	SUBTOTAL (bamboo veneer production line):	**2**	**sets**		**20,670.00**

3. SPARE PARTS

CYM-101	16" HIGH SPEED TCT SAW	1	pc	150.00	150.00
CYM-102	KNOT REMOVING KNIFE	3	pcs	50.00	150.00
CYM-103	10" HIGH SPEED TCT SAW	120	pcs	130.00	15,600.00
CYM-104	1 1/2" PLANING CUTTER(SIZING CUTTER)	15	pcs	75.00	1,125.00
CYM-104	KNOT REMOVING KNIFE	3	pcs	30.00	90.00
CYM-106	LARGE CUTTING KNIFE (TOP)	8	pcs	90.00	720.00
CYM-106	SMALL CUTTING KNIFE (LOWER)	8	pcs	80.00	640.00
CYM-106	CUTTING KNIFE (LEFT)	8	pcs	60.00	480.00
CYM-106	CUTTING KNIFE (RIGHT)	8	pcs	60.00	480.00
CYM-006F	14" HIGH SPEED TCT SAW	1	pc	140.00	140.00
CYM-108	GASKET	1	pc	100.00	100.00
CYM-068F	Diamond wheel for sharpening (Thickness: 6mm)	1	pc	220.00	220.00
CYM-068F	Diamond wheel for sharpening (Thickness: 10mm)	1	pc	250.00	250.00
CYM-111 4'	SANDING PAPER 60#	35	pcs	42.00	1,470.00

錦榮竹木企業股份有限公司
彰化縣鹿港鎮民族路97號
NO.97, MIN TSU RD., LUKANG CHEN,
CHANG HUA HSIEN, TAIWAN, R.O.C
Tel: +886 4 777 6868
Fax: +886 4 778 3909, 777 2799
e-mail:cybamboo@ms2.hinet.net

CHIN YUNG BAMBOO & WOOD CO., LTD.

OFFER SHEET

Messrs.: **RSA Bamboo (South Africa)**

Date: JUNE 13, 2017

CYM-111 4'	SANDING PAPER 80#	35	pcs	38.00	1,330.00
CYM-111 4'	SANDING PAPER 100#	50	pcs	35.00	1,750.00
CYM-111 4'	SANDING PAPER 180#	50	pcs	35.00	1,750.00
CYM-031AB	18" PEELING KNIFE	1	pc	320.00	320.00
CYM-031AB	LOCATING KNIFE	5	pcs	15.00	75.00
CYM-066A	GRINDING WHEEL	2	pcs	80.00	160.00
	SUBTOTAL (SPARE PARTS):	**356**	**pcs**		**27,000.00**
	TOTAL:				**342,840.00**

CHIN YUNG BAMBOO & WOOD CO., LTD.

Jacky Hong /CEO

G.5 Activated Carbon Quotation

HeBei Baisite Technology Co.,Ltd

Official Quotaion :

Product name: Coconut Activated Carbon
Shape: Granular
Mesh Size: 12x40 mesh
Color : Black
Price: USD 1968/Ton CIF Cape Town South Africa
Packing: 25kg pp bag or 50kg pp bag or Ton bag ,or as your requirement
Payment: T/T in advance
Delivey time: 2-5 days after your order confrimed
Validity : 15 days

Kevin,
2017,06-13

G.6 Biochar Quotation

SEEK 时科

Professional for bamboo biochar organic fertilizer

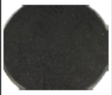
Seek Bio-Technology (Shanghai) Co.,Ltd

Tel: 021-52962258 Ext:8025 Fax：021-52239008

Contact：Gloria Mobile: + 86 133 8186 1182 E-mail：export3@seekfertilizer.com

Address：Bldg. A7,No.298, Lane 3509,South Hongmei Road, Minhang District, Shanghai, China www.seekfertilizer.com

Quote on 8th, June,2017 , Valid until 30, Sep 2017

No.	Item No.	Picture	Packing	Specification	FOB Price
1	SEEK BBP No.6 Bamboo Biochar powder state		25kg/bag	Carbon≥75% Ash ≤4.5%	USD$ 520/Metric Ton
2	SEEK BBP No.6 Bamboo Biochar flake state		25kg/bag	Carbon≥75% Ash ≤4.5%	USD$ 640/Metric Ton

G.7 Bamboo Laminated Board Quotation

Factory: Zhangzhou Pingxin Wood & Bamboo Co., Limited

ADD: NO. 8, HuanChengLi Xiaguan Village, Guanpi Town ,Zhao'an ,Zhangzhou City ,China.

www.chinabamboopanels.com mob. +86 18759229120 email: marcehuang@86pxplywood.com

Export Office: Xiamen Jiaxing Imp. And Exp. Co., Ltd

ADD: Rm 301. No. 68, Jinshan Community Huli Dis. Xiamen, City China.

Tel: 86 592 8878007 Fax: 86 592 5334829

Date: 2017-06-14

Importer	Stellenbosch Technology Centre Laboratory for Advanced Manufacturing	**Invoice Number:**	
		Purchase order no:	
Add:	Stellenbosch University Private Bag X1 Matieland 7602 South Africa	**Price Term:**	CNF Cape Town , South Africa
		Mark:	
Phone:	+27 (0)73 805 4005	**Shipping Port:**	Xiamen ,china
		Destination Port:	Cape Town, South Africa
		H.S.code:	4409211090

Formal Bamboo Panels Offer

The buyer and the seller agree to each other on the business according to the conditions and terms listed below:

Item	Bamboo Panels			
S. NO:	Description	Quantity Pieces	Price (USD / pcs)	Amount USD
1	Bamboo Panels A grade: Horizontal Pressed. Carbonized Color. 1220 x 2440 x 40mm	150.00	136.350	20452.50
2	Bamboo Panels A grade: Cross Horizontal Pressed. Carbonized Color. 1220 x 2440 x 40mm	150.00	158.850	23827.50
			Total USD	44280.00
	shipping freight 2 x 20GP to Cape Town, South Africa 1062 usd / 20Gp			2124.00
Final Total		300 pcs	46404.00 USD	

Solid Bamboo Panels of A grade

Color: Carbonized color.

Surface: Sanded.

Moisture: 10% - 12% , Carbonized colormatching.

Glue included: E1 glue.

Bending Max.: max. 1 mm per meter.

Density:750 kgs / M3 (tolerance +50 kgs , - 50 kgs.)

Size: Thickenss tolerance - 0mm, + 0.5-1mm.

Payment:

30% after receiing pro-forma Invoice

70% by L/C at sight issued from international bank.

G.8 Lime Quotation

LIME DISTRIBUTORS (PTY) LTD

Registration No. 1978/002117/07

HEAD OFFICE

• Block F, First Floor, Wild Fig Business Park • Cranberry Street • Honeydew • PO Box 2043 • Randburg • 2125
• Tel: 011-795 4900 • Fax: 011-795 4923 • E-mail: limeorders@idwala.co.za • Website: www.idwala.co.za

3 March 2017

Dewald Burger
Per E-mail: dewaldburger18@gmail.com

Dear Dewald,

Quotation for the supply of Hydrated Lime from Powerville (Vereeniging)

Further to your recent request for a quotation we have pleasure in detailing our offer below.

Product Description	Packaging	Product Price per Ton	Transport details and Price per Ton
Hydrated Lime	25kg pockets, palletised and stretch wrapped	R2 450-00	N/A – Collection from Vereeniging

The prices quoted above exclude Value Added Tax (VAT) and are valid until 31 March 2017.

Transport

- You may collect the product from Vereeniging using a flatbed, drop-side or interlink truck.

Terms of Payment

- Payment may be made via Electronic Funds Transfer, or
- on credit terms of 30 days from date of statement (once a credit application has been approved)

We thank you for the opportunity to submit this quotation. Should you require any further information please do not hesitate to contact the writer hereof.

Regards, Wendy

Wendy Eyre
Sales Co-Ordinator
Idwala Industrial Holdings Limited
First Floor, Block F, Wild Fig Business Park
Cranberry Street, Honeydew, 2040
T +27 11 795 4900, F +27 11 795 4923
WEyre@idwala.co.za ; www.idwala.co.za

Directors JJB Welsh, WPW Brown, GJ Mangotlo, RH Ramthol